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Universal Energy Systems, Inc.

UES

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The Air Force High School Apprenticeship Program's purpose is to place outstanding high school students whose interests are in the areas of mathematics, engineering, and science to work in a laboratory environment. The students selected to participate work in an Air Force Laboratory for a duration of 8 weeks during their summer vacation.

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UNITED STATES AIR FORCE

HIGH SCHOOL APPRENTICESHIP PROGRAM

1990

PROGRAM MANAGEMENT REPORT

VOLUME III OF IV

UNIVERSAL ENERGY SYSTEMS, INC.

Program Director, UES
Rodney C. Darrah

Program Manager, AFOSR
Lt. Col. Claude Cavender

Program Administrator, UES
Susan K. Espy

Submitted to

Air Force Office of Scientific Research

Bolling Air Force Base

Washington, DC

December 1990

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INTRODUCTION

In the near future the United States may face shortages of scientists and engineers in fields such as physics, electronic engineering, computer science and aeronautical engineering. High school students are currently not selecting to prepare for careers in these areas in numbers large enough to match the projected needs in the United States.

The Air Force faces "a formidable challenge - the acquisition and retention of the technological competence needed to ensure a strong national security, both in-house and in the industrial and academic base which supports defense preparedness." The Director of the Office and Science of Technology Policy in the Executive Office of the President in 1979 responded to this need by requesting the federal agencies to incorporate in their contract research programs the mechanisms to stimulate career interests in science and technology in high school students showing promise in these areas. The Air Force High School Apprenticeship Program is an example of the response to this.

Under the Special Studies section of the Summer Faculty Research Program an Air Force High School Apprenticeship was initiated. This program's purpose is to place outstanding high school students whose interests are in the areas of engineering and science to work in a laboratory environment. The students who were selected to participate worked in one of the Air Force Laboratories for a duration of 8 weeks during their summer vacation.

There has been a few incidents concerning misuse of the computers in the laboratories. On two separate occasions the laboratory has had to revoke computer privileges on four high school students. Both of these incidents happened at the same laboratory.

Two years ago two students wrote a program to shut down the computer system at the laboratory and to steal users access codes. These students were removed from the laboratory and one of the students was dismissed from the program, while the other student finished his apprenticeship at the UES facility.

This year a similar incident happened. Two other students were involved with basically the same incident. One student wrote a program that would send repeating messages to the various computer terminals. Included in this program was a password interception program were the users would type in their password and the program would retrieve that password. The other student involved also wrote and executed a password stealing program, and was involved in the unauthorized use of a government computer in writing a fraudulent letter. The student also obtained unauthorized access to a computer modem.

The Air Force High School Apprenticeship Program was modeled after the Army's High School Program, which is very successful.

The following time schedule was used in order to accomplish this effort.

TABLE 1
AIR FORCE HIGH SCHOOL
APPRENTICESHIP PROGRAM

Calendar of Activities

December	o Identify schools and laboratories for participation o Prepare informational material for schools and installations application forms for students and mentors, and covering letters. o Disseminate information o Recruit apprentices, mentors
January	o Send student applications to teachers
February	o Applications with teacher recommendations o Receive mentors' project descriptions and student requirements o Make preliminary selection of students for referral to mentor
March	o Make preliminary matching of students with mentors; send letters with several student applications to each mentor o Mentors interview students, inform UES of choice
April	o Send letters of placement to students, with acceptance forms to be signed by them and parents and returned to UES o Place 2nd year apprentices o Make final matches o See that security clearances are started, where applicable o (Mentors provide background reference material to chosen apprentices) o Encourage enrichment activities: arrange for films, speakers, tours, etc.
May	o Send letters to students and mentors re-opening session o Send students Apprentice Handbook
June	o Arrange general orientation for students and mentors
July, August	o Administer and monitor apprenticeships o Check on enrichment activities o Distribute evaluation forms to students and mentors
September	o Analyze evaluations o Prepare final report to Air Force

RECRUITING AND SELECTION

Application packages and the flyer were distributed to the laboratories and to the various high schools within convenient driving distance of the laboratories (typically less than 20 miles).

There was a total of 516 applications received by UES on the program. When the applications were received, a copy was sent to the appropriate laboratory for review. The laboratory mentor screened the applications and conducted personnel interviews with the high school students then sent UES a prioritized list of their applicants. There were a total of 132 participants on the program, selected from the 516 applications.

The laboratories participating in the program along with the number of students assigned to the laboratory is listed below:

Aero Propulsion Laboratory	7
Armament Laboratory	16
Armstrong Aerospace Medical Research Laboratory	7
Arnold Engineering and Development Center	6
Avionics Laboratory	6
Astronautics Laboratory	12
Engineering and Services Center	15
Electronic Technology Laboratory	5
Flight Dynamics Laboratory	9
Geophysics Laboratory	7
Materials Laboratory	1
Occupational and Environmental Health Laboratory	3
Rome Air Development Center	15
School of Aerospace Medicine	13
Weapons Laboratory	10

Participant Laboratory Assignment
1990 High School Apprenticeship Program

Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Bold
2. Hee Sun Choung
3. Katharine Day
4. Chris Hatch
5. Chet Nieter
6. Jennifer Pollock
7. Carol Rogers

Armament Laboratory
Eglin Air Force Base, Florida

1. Steven Bryan
2. Toyna Cook
3. Heather Cox
4. Kathryn Deibler
5. Chris Ellis
6. Dana Farver
7. Kenneth Gage
8. Reid Harrison
9. Derek Holland
10. Christine Riendeau
11. Lisa Schmidt
12. Patricia Tu
13. Troy Urquhart
14. Gregory VanWiggeren
15. Danielle Walker
16. Eric White

Armstrong Aerospace Medical Research Laboratory
Wright-Patterson Air Force Base, Ohio

1. Rex Ballinger
2. Douglas Brungart
3. Caroline Chuang
4. Keisha Hayes
5. Douglas Marshak
6. Jeremiah Rogers
7. James Shamiyeh

Arnold Engineering and Development Center
Arnold Air Force Base, Tennessee

1. Timo[illegible] Craddock
2. Myra [illegible]edley
3. Julie R[illegible]
4. Jonathan Sanders
5. Jason Scott
6. Gerald Turner

Astronautics Laboratory
Edwards Air Force Base, California

1. Alisha Conrow
2. Debra Meyer
3. John Moro
4. Lloyd Neurauter
5. Joseph Padilla
6. Melanie Pyle
7. Thomas Quinn
8. Tracy Reed
9. Benjamin Sommers
10. Stephanie VanMeter
11. Rebecca Weston
12. David Youmans

Avionics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Brian Barclay
2. Mark Boeke
3. Michael Chabinyc
4. David Collins
5. Austin Flack
6. Jerard Wilson

Engineering and Services Center
Tyndall Air Force Base, Florida

1. Jennifer Brewer
2. Philip Dorsch
3. David Eshleman
4. Richard Hartzer
5. Thor Johnson
6. Tracy Lamb
7. Brent Miller
8. Debra Piechowiak
9. Jonathan Protz
10. Julie Scruggs
11. Michael Stone
12. Amy Thomas
13. Michael Thompson
14. Jeffrey Ward
15. Robin Woodworth

Electronic Technology Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Brewer
2. Matt Elwood
3. Shelly Knupp
4. Christopher O'Dell
5. Suzette Yu

Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Jean Ay
2. Matthew Becker
3. Wendy Choate
4. Andrea Dean
5. Rachael Lyon
6. Cathie Moore
7. Roderick Morgan
8. Stanley Wall
9. Douglas Wickert

Geophysics Laboratory
Hanscom Air Force Base, Massachusetts

1. Stephen Britten
2. Weihaw Chuang
3. Christopher Guild
4. Jason Klingensmith
5. Galen McKinley
6. Jeffrey Sayasane
7. Paul Swietek

Materials Laboratory
Wright-Patterson Air Force Base, Ohio

1. Jennifer Walker

Occupational and Environment Health Laboratory
Brooks Air Force Base, Texas

1. Gary New
2. Andrea Perez
3. Michael Smid

Rome Air Development Center
Griffiss Air Force Base, New York

1. Daniel Abbis
2. Mark Anania
3. Bridget Bordiuk
4. Todd Gleason
5. Christopher Hailes
6. Edward Holmes
7. Kimberly King
8. Kathryn Lee
9. Jason Lenio
10. Kevin Olson
11. David Petrillo
12. Thomas Potter
13. Daniel Russell
14. Philip Schremmer
15. Eric Shaw

School of Aerospace Medicine
Brooks Air Force Base, Texas

1. Anthony Barnes
2. Whitney Brandt
3. Deann Cooper
4. Matthew Felder
5. Christopher Hudson
6. Sonya Longbotham
7. Brian McBurnett
8. Heather Neville
9. Lori Olenick
10. Joanna Saucedo
11. Wendy Shields
12. Brent Strawn
13. John Taboada

Weapons Laboratory
Kirtland Air Force Base, New Mexico

1. David Cochrell
2. Gregory Hays
3. David Knapp
4. Aaron Laing
5 Kerim Martinez
6. Ryan McAlhaney
7. Margaret Morecock
8. Philip Ortiz
9. Brian Rizzoli
10. Chris Stoltenberg

INFORMATION PACKAGE

23 March 1990

Dear :

Enclosed are the mentor applications forms for the 1990 USAF High School Apprenticeship Program. The mentors and project descriptions have been approved by UES.

Enclosed are the applications for the High School Apprenticeship program for the summer of 1990. The following mentors and previous high school participants have been matched and selected to work with each other for the coming summer.

Student	Mentor
1.	
2.	
3.	

The following is a previous high school participant in the program and is selected to participate in the program for this summer. He needs to be matched with one of the approved mentors for this summer.

Student
1.

The remainder of the students need to be evaluated by the approved mentors for possible selection in the program for this summer. Please provide to UES a listing of the mentor recommendations for students by 15 April 1990.

We have a total of 100 positions available on the program for this summer. We will select as many as possible to fill this available positions. We anticipate that about 15 high school students will be selected to participate with the mentors at the Rome Air Development Center.

If you have any questions concerning this information, please do not hesitate to contact us.

Sincerely,

UNIVERSAL ENERGY SYSTEMS, INC.

Rodney C. Darrah
Program Director

Enclosure

xc: Lt. Col. Claude Cavender

MODEL PLACEMENT LETTER TO STUDENT

13 March 1991

1~
2~
3~

Dear 4~:

Congratulations! You have been selected to participate in the Air Force Office of Scientific Research High School Apprenticeship Program as an apprentice to 5~ at the 6~ to work on Project: "7~" from June 18 to August 10, 1990. Enclosed is an acceptance form for you and your parent or guardian to sign. Also enclosed is your W-4 form which needs to be filled out and returned along with your acceptance form to me by May 11, 1990.

The Apprenticeship Program provides an exciting opportunity for you, and we hope you will take advantage of the work experience to learn more about scientific research, career opportunities in science and engineering, and the education necessary to prepare yourself for such careers. On June 18, 1990, the first day of the program, you are expected to attend an orientation session with other apprentices and mentors and to ask questions about any concerns you might have. Many of those concerns are discussed in the Apprentice Handbook which is enclosed. The Handbook also contains suggestions for getting the most out of the summer experience, and references to other work experience programs and financial assistance available for college education. Please read the Handbook before the orientation session, so that time will not be used for questions answered in the book.

You will be expected to begin work promptly at 8:00 a.m. on June 18. If for any reason you cannot begin work on that day, or cannot report to work on any future work day, you must inform your mentor at 8~.

We hope you will enjoy your apprenticeship. I will be available throughout the summer should problems arise that cannot be solved by your mentor.

Sincerely,

UNIVERSAL ENERGY SYSTEMS, INC.

Rodney C. Darrah
Program Director

RCD/mt

STUDENT ACCEPTANCE FORM

for participation in

Air Force Office of Scientific Research

High School Apprenticeship Program, 1990

I, 1~, accept the position of apprentice in the Air Force Office of Scientific Research High School Apprenticeship Program from June 18, 1990 to August 10, 1990 to work with 2~ at the 3~ on Project: "4~". I understand that I will receive a stipend of $5~ for the summer apprenticeship for which I must participate during the entire session.

Date

Signature of student

High School

PARENT CONSENT

As the parent/guardian, I certify that my son/daughter/ward has my permission to participate in this project for secondary school students. It is my understanding that he/she will be subject to the regulations of the host institution and the project. I understand that should a health emergency arise I will be notified, but that if I cannot be reached by telephone, such medical treatment as deemed necessary by competent medical personnel is authorized.

Date

Signature of parent

Daytime phone

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

1. How did you hear about program?

   - o Previous mentor
   - o Notice on bulletin board
   - o Memo from personnel office
   - o Verbal request from personnel office
   - o Other, specify____________ ____________________

2. Did you volunteer to be a mentor?

   Yes__ No__

3. Did the student application provide sufficient information?

   Yes__ No__

4. If no, what additional information would you want to see included on the student application form?____

   ____

   ____

5. Did you interview the student who was placed in your laboratory before the program started?

   Yes__ No__

6. If no, would an interview have been useful?

   Yes__ No__

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   A lot__ Some__ Not at all__

8. How much did the student contribute to the research of your laboratory?

   A lot__ Some__ Not at all__

9. How would you rate the student's performance?

   Excellent__ Fair__ Poor__

10. Would like to participant as a mentor for the program next summer?

Yes___ No___ If No, Why?________________________________

11. Would you want the same student in your laboratory next summer?

Yes___ No___ If No, Why?________________________________

12. Did the work of the student influence his/her choice of

a. courses in coming school year? ___Yes ___No ___Don't know

Explain ____

b. career choice? ___Yes ___No ___Don't know

Explain ____

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

AERO PROPULSION LABORATORY

1. How did you hear about program?

   6 Previous mentor
   0 Notice on bulletin board
   0 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   Assistant Chief Scientists.

2. Did you volunteer to be a mentor?

   7 Yes
   0 No

3. Did the student application provide sufficient information?

   7 Yes
   0 No
   0 Don't Know

4. If no, what additional information would you want to see included on the student application form?

   Specific information regarding computer experience.

5. Did you interview the student who was placed in your laboratory before the program started?

   4 Yes
   3 No

6. If no, would an interview have been useful?

   6 Yes
   1 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   1 Some
   0 Not at all

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   1 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   2 A lot
   5 Some
   0 Not at all

9. How would you rate the student's performance?

   4 Excellent
   3 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   7 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   7 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 0 - Yes 1 - No 6 - Don't Know

   Explain:

   She was already planning on an Engineering degree at U. of K.

   b. career choice? 0 - Yes 1 - No 6 - Don't know

   Explain:

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARMAMENT LABORATORY

1. How did you hear about program?

    11 Previous mentor
    0 Notice on bulletin board
    3 Memo from personnel office
    0 Verbal request from personnel office
    2 Other, specify:__________

    Section Chief.

    I have been a mentor for 3 years.

2. Did you volunteer to be a mentor?

    16 Yes
    0 No

3. Did the student application provide sufficient information?

    12 Yes
    1 No
    3 N/A

4. If no, what additional information would you want to see included on the student application form?

    I did not see the application, or pay much attention to it. I just accepted the student assigned to me.

5. Did you interview the student who was placed in your laboratory before the program started?

    10 Yes
    6 No

6. If no, would an interview have been useful?

    5 Yes
    0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    15 A lot
    1 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

    10 A lot
    6 Some
    0 Not at all

9. How would you rate the student's performance?

    15 Excellent
    1 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    14 Yes
    2 No
    If No, Why?

    I will be away.

11. Would you want the same student in your laboratory next summer?

    10 Yes
    6 No
    If No, Why?

    All the no responses indicate the students will be attending college and not eligible for the program.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 5 - Yes 2 - No 9 - Don't know

    Explain:

    Most of the comments indicate that the courses are already set. But toward the math and science courses.

b. career choice? 7 - Yes 1 - No 8 - Don't know

Explain:

The comments consist that students are still deciding, two of the students definitely want in the science careers.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

1. How did you hear about program?

    7 Previous mentor
    0 Notice on bulletin board
    0 Memo from personnel office
    0 Verbal request from personnel office
    0 Other, specify:__________

2. Did you volunteer to be a mentor?

    7 Yes
    0 No

3. Did the student application provide sufficient information?

    6 Yes
    0 No

4. If no, what additional information would you want to see included on the student application form?

    I didn't see the application form.

5. Did you interview the student who was placed in your laboratory before the program started?

    2 Yes
    5 No

6. If no, would an interview have been useful?

    2 Yes
    2 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    3 A lot
    4 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

   2 A lot
   5 Some
   0 Not at all

9. How would you rate the student's performance?

   6 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   4 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   6 Yes
   1 No
   If No, Why?

   She graduated.

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 2 - Yes 1 - No 4 - Don't know

   Explain:

   Gained additional knowledge & training in lab that allowed testing out of some pre-requisite courses.

   b. career choice? 2 - Yes 2 - No 3 - Don't know

   Explain:

   Comments include that the student has new insight to engineering, and another student wants to go into medicine

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARNOLD ENGINEERING AND DEVELOPMENT CENTER

1. How did you hear about program?

   1 Previous mentor
   0 Notice on bulletin board
   2 Memo from personnel office
   2 Verbal request from personnel office
   1 Other, specify:__________

   Supervisor.

2. Did you volunteer to be a mentor?

   5 Yes
   1 No

3. Did the student application provide sufficient information?

   6 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   4 Yes
   2 No

6. If no, would an interview have been useful?

   1 Yes
   1 No
   0 Maybe

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   4 A lot
   2 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

    4 A lot
    2 Some
    0 Not at all

9. How would you rate the student's performance?

    6 Excellent
    0 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    6 Yes
    0 Maybe
    0 No
    If No, Why?

11. Would you want the same student in your laboratory next summer?

    6 Yes
    0 No
    If No, Why?

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 1 - Yes 3 - No 2 - Don't know

    Explain:

    The no responses indicate that courses are pre-determined and not many options.

    b. career choice? 4 - Yes 0 - No 2 - Don't know

    Explain:

    Heightened interest in chemistry/chemical engineering.

    Solidified his intent to pursue an engineering career.

If you have suggestions or comments on the program, please use the space below.

I would suggest that students requiring a security clearance he given advanced notice so that the necessary processing could be completed prior to their coming to work. A ten week program (instead of 8) should be offered as an option for the students.

This program was a very positive experience for me as well as her. I would enjoy participating in the program again.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ASTRONAUTICS LABORATORY

1. How did you hear about program?

   5 Previous mentor
   0 Notice on bulletin board
   1 Memo from personnel office
   1 Verbal request from personnel office
   2 Other, specify:__________

   Request from XRX.

2. Did you volunteer to be a mentor?

   9 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   1 No

4. If no, what additional information would you want to see included on the student application form?

   At a high school level there isn't a lot of detailed scientific technical questions you can ask for.

5. Did you interview the student who was placed in your laboratory before the program started?

   4 Yes
   5 No

6. If no, would an interview have been useful?

   4 Yes
   1 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   7 A lot
   2 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   6 A lot
   3 Some
   0 Not at all

9. How would you rate the student's performance?

   9 Excellent
   0 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   9 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   9 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 2 - Yes 4 - No 3 - Don't know

   Explain:

   Most of the responses indicate that student's courses are already set for the upcoming year.

   b. career choice? 1 - Yes 3 - No 5 - Don't know

   Explain:

   Two of the comments were that the student's have their career's planned, even as far as job opportunities. One student wants to go in the medical profession.

If you have suggestions or comments on the program, please use the space below.

Let the students accrue leave (annual & sick) and let them work more than 40 days!

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

AVIONICS LABORATORY

1. How did you hear about program?

   3 Previous mentor
   1 Notice on bulletin board
   1 Memo from personnel office
   1 Verbal request from personnel office
   0 Other, specify:__________

2. Did you volunteer to be a mentor?

   6 Yes
   0 No

3. Did the student application provide sufficient information?

   4 Yes
   2 No

4. If no, what additional information would you want to see included on the student application form?

   Previous police record and descriptions of any court imposed fines or punishment.

5. Did you interview the student who was placed in your laboratory before the program started?

   0 Yes
   6 No

6. If no, would an interview have been useful?

   2 Yes
   4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   2 A lot
   4 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   2 Some
   0 Not at all

9. How would you rate the student's performance?

   5 Excellent
   0 Fair
   1 Poor

10. Would like to participant as a mentor for the program next summer?

   5 Yes
   1 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   5 Yes
   1 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 1 - Yes 3 - No 2 - Don't know

   Explain:

   I think his courses were pretty well planned out before he came to the lab. What he learned here probably reinforced his choices rather than changing them.

   b. career choice? 2 - Yes 2 - No 2 - Don't know

   Explain:

   All of the responses indicate the students' have chosen a career; from chemical engineer to computer science.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ENGINEERING AND SERVICES CENTER

1. How did you hear about program?

   9 Previous mentor
   1 Notice on bulletin board
   0 Memo from personnel office
   1 Verbal request from personnel office
   4 Other, specify:__________

   The comments for the Other category were notifications from AFESC staff.

2. Did you volunteer to be a mentor?

   14 Yes
   1 No

3. Did the student application provide sufficient information?

   14 Yes
   1 No

4. If no, what additional information would you want to see included on the student application form?

   Never saw a student application from.

5. Did you interview the student who was placed in your laboratory before the program started?

   4 Yes
   11 No

6. If no, would an interview have been useful?

   8 Yes
   4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   9 A lot
   5 Some
   1 Not at all

8. How much did the student contribute to the research of your laboratory?

   9 A lot
   5 Some
   1 Not at all

9. How would you rate the student's performance?

   14 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   13 Yes
   2 No
   If No, Why?

   The "no" comments were because of the time that it takes, and the other mentor will be traveling.

11. Would you want the same student in your laboratory next summer?

   15 Yes
   0 No
   If No, Why?

   If I were to do it again.

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 5 - Yes 4 - No 6 - Don't know

   Explain:

   The majority of the comments as before where that the courses are already determined.

   b. career choice? 4 - Yes 3 - No 8 - Don't know

   Explain:

   The comments range from students that have not decided, to a student choosing to be an engineer and Air Force pilot.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ELECTRONIC TECHNOLOGY LABORATORY

1. How did you hear about program?

   0 Previous mentor
   0 Notice on bulletin board
   1 Memo from personnel office
   0 Verbal request from personnel office
   4 Other, specify:__________

   Through Lab Operation Division (ELA).

   Verbal request from boss.

   Co-worker.

2. Did you volunteer to be a mentor?

   4 Yes
   1 No

3. Did the student application provide sufficient information?

   5 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   3 Yes
   2 No

6. If no, would an interview have been useful?

   1 Yes
   1 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   5 A lot
   0 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

    3 A lot
    2 Some
    0 Not at all

9. How would you rate the student's performance?

    4 Excellent
    1 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    5 Yes
    0 No
    If No, Why?

11. Would you want the same student in your laboratory next summer?

    4 Yes
    1 No
    If No, Why?

    Student has limited interest in research.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 0 - Yes 1 - No 4 - Don't know

    Explain:

    Responses indicate that courses are pre-determined.

    b. career choice? 0 - Yes 0 - No 5 - Don't know

    Explain:

    I think she has gained an appreciation for the challenging nature of research.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

FLIGHT DYNAMICS LABORATORY

1. How did you hear about program?

   4 Previous mentor
   0 Notice on bulletin board
   0 Memo from personnel office
   1 Verbal request from personnel office
   3 Other, specify:__________

   Branch office.

   WRDC/FIOP

2. Did you volunteer to be a mentor?

   8 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   3 Yes
   5 No

6. If no, would an interview have been useful?

   4 Yes
   1 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   5 A lot
   3 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

5 A lot
3 Some
0 Not at all

9. How would you rate the student's performance?

7 Excellent
1 Fair
0 Poor

10. Would like to participant as a mentor for the program next summer?

7 Yes
1 No
If No, Why?

Only if a project is available for use by student!

11. Would you want the same student in your laboratory next summer?

6 Yes
2 No
If No, Why?

Comments indicate student's are not eligible.

12. Did the work of the student influence his/her choice of

a. courses in coming school year? 1 - Yes 2 - No 5 - Don't know

Explain:

Student had already chosen Engineering Curriculum for College.

b. career choice? 3 - Yes 1 - No 4 - Don't know

Explain:

Student already targets Aerospace future.

If you have suggestions or comments on the program, please use the space below.

Work must be available that a student can get involved in for the duration of there stay. If it is not, I will not take any more students.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

GEOPHYSICS LABORATORY

1. How did you hear about program?

   2 Previous mentor
   0 Notice on bulletin board
   3 Memo from personnel office
   0 Verbal request from personnel office
   0 Other, specify:__________

2. Did you volunteer to be a mentor?

   5 Yes
   0 No

3. Did the student application provide sufficient information?

   5 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   1 Yes
   4 No

6. If no, would an interview have been useful?

   3 Yes
   1 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   3 A lot
   2 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   3 A lot
   2 Some
   0 Not at all

9. How would you rate the student's performance?

   5 Excellent
   0 Fair
   0 Poor

10. Would like to participate as a mentor for the program next summer?

   5 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   5 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 0 - Yes 0 - No 5 - Don't know

      Explain:

      Courses probably selected prior to the summer job.

   b. career choice? 0 - Yes 1 - No 4 - Don't know

      Explain:

      Was already planning to enter MIT in an engineering field.

If you have suggestions or comments on the program, please use the space below.

The main comment is that they would like to see the program expanded to 10 to 12 weeks, also that the stipend should be raised to compete with jobs outside of research.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

MATERIALS LABORATORY

1. How did you hear about program?

   0 Previous mentor
   0 Notice on bulletin board
   0 Memo from personnel office
   1 Verbal request from personnel office
   0 Other, specify:__________

2. Did you volunteer to be a mentor?

   1 Yes
   0 No

3. Did the student application provide sufficient information?

   1 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   0 Yes
   1 No

6. If no, would an interview have been useful?

   1 Yes
   0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   1 A lot
   0 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   1 A lot
   0 Some
   0 Not at all

9. How would you rate the student's performance?

   1 Excellent
   0 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   1 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   1 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 0 - Yes 0 - No 1 - Don't know

      Explain:

      Student is pursuing a career in Civil Engineering.

   b. career choice? 0 - Yes 1 - No 0 - Don't know

      Explain:

If you have suggestions or comments on the program, please use the space below.

She was really a pleasure to work with. She was self motivated and a diligent worker who was genuinely interested in everything going on withır the lab. She did a outstanding job. Would like to see her back next year!

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

OCCUPATIONAL AND ENVIRONMENT HEALTH LABORATORY

1. How did you hear about program?

    0 Previous mentor
    0 Notice on bulletin board
    1 Memo from personnel office
    0 Verbal request from personnel office
    1 Other, specify:__________

    My supervisor.

2. Did you volunteer to be a mentor?

    1 Yes
    1 No

3. Did the student application provide sufficient information?

    2 Yes
    0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

    0 Yes
    2 No

6. If no, would an interview have been useful?

    2 Yes
    0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    0 A lot
    2 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

    2   A lot
    0   Some
    0   Not at all

9. How would you rate the student's performance?

    2   Excellent
    0   Fair
    0   Poor

10. Would like to participant as a mentor for the program next summer?

    2   Yes
    0   No
        If No, Why?

11. Would you want the same student in your laboratory next summer?

    2   Yes
    0   No
        If No, Why?

12. Did the work of the student influence his/her choice of

    a. courses in coming school year?   0 - Yes   0 - No   2 - Don't know

       Explain:

       Student was already interested in science courses.

    b. career choice?   0 - Yes   0 - No   2 - Don't know

       Explain:

       Student is already set to take engineering in college.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ROME AIR DEVELOPMENT CENTER

1. How did you hear about program?

    4 Previous mentor
    0 Notice on bulletin board
    3 Memo from personnel office
    2 Verbal request from personnel office
    2 Other, specify:__________

    Director of Photonics Labs.

    Branch Chief sent me a memo.

2. Did you volunteer to be a mentor?

    10 Yes
    1 No

3. Did the student application provide sufficient information?

    10 Yes
    1 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

    0 Yes
    11 No

6. If no, would an interview have been useful?

    6 Yes
    5 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    4 A lot
    7 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

   3 A lot
   8 Some
   0 Not at all

9. How would you rate the student's performance?

   10 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

    8 Yes
    3 No
    If No, Why?

    The "no" responses indicated that they did not have the time to devote to the students.

11. Would you want the same student in your laboratory next summer?

    8 Yes
    3 No
    If No, Why?

    Give someone else the opportunity to work here.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 2 - Yes 2 - No 7 - Don't know

       Explain:

       Courses pre-determined but students were influenced for courses at the advanced levels.

    b. career choice? 3 - Yes 2 - No 5 - Don't know

       Explain:

       The majority of the comments were that the career choices were reinforced.

If you have suggestions or comments on the program, please use the space below.

Great Program! Thanks!

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

SCHOOL OF AEROSPACE MEDICINE

1. How did you hear about program?

 7 Previous mentor
 1 Notice on bulletin board
 0 Memo from personnel office
 1 Verbal request from personnel office
 4 Other, specify:________

 Laboratory Chief Scientist

 Letter from SAM/CA.

2. Did you volunteer to be a mentor?

 13 Yes
 0 No

3. Did the student application provide sufficient information?

 13 Yes
 0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

 4 Yes
 8 No

6. If no, would an interview have been useful?

 4 Yes
 4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

 12 A lot
 1 Some
 0 Not at all

8. How much did the student contribute to the research of your laboratory?

9 A lot
4 Some
0 Not at all

9. How would you rate the student's performance?

11 Excellent
2 Fair
0 Poor

10. Would like to participant as a mentor for the program next summer?

12 Yes
0 No
If No, Why?

11. Would you want the same student in your laboratory next summer?

11 Yes
2 No
If No, Why?

The student stated she did not have the patience for research work. Therefore, I would prefer giving another student an opportunity to participate in next year's program.

12. Did the work of the student influence his/her choice of

a. courses in coming school year? 1 - Yes 3 - No 9 - Don't know

Explain:

The responses indicated that courses are pre-determined, although one comment indicated that it influenced the student's college courses.

b. career choice? 5 - Yes 0 - No 8 - Don't know

Explain:

Indicated a change from nursing to biological research.

If you have suggestions or comments on the program, please use the space below.

This is an excellent program. It helps students realize what "research" means, and gives them some independence in the laboratory setting.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

WEAPONS LABORATORY

1. How did you hear about program?

    1 Previous mentor
    0 Notice on bulletin board
    4 Memo from personnel office
    1 Verbal request from personnel office
    2 Other, specify:__________

    Supervisor.

    Program Coordinator on site.

2. Did you volunteer to be a mentor?

    8 Yes
    0 No

3. Did the student application provide sufficient information?

    8 Yes
    0 No

4. If no, what additional information would you want to see included on the student application form?

    One mentor commented that questions should be asked concerning technical capabilities.

    I chose a student I was familiar with, I never saw the applications.

5. Did you interview the student who was placed in your laboratory before the program started?

    1 Yes
    7 No

6. If no, would an interview have been useful?

    3 Yes
    3 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   8 A lot
   0 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   6 A lot
   2 Some
   0 Not at all

9. How would you rate the student's performance?

   8 Excellent
   0 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

    7 Yes
    1 No
    If No, Why?

    Just every few years.

11. Would you want the same student in your laboratory next summer?

    7 Yes
    1 No
    If No, Why?

    Student starting college.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 3 - Yes 1 - No 4 - Don't know
    Explain:

    Most comments were that the courses have already been set. One commented that the student changed from nuclear engineering to electrical engineering.

    b. career choice? 4 - Yes 1 - No 3 - Don't know
    Explain:

    Comments were that the work was parallel to career choices.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
APPRENTICE EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A HIGH SCHOOL STUDENT)

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL)

I. <u>How much were you exposed to each of the following during your summer apprenticeship? (Circle one letter per line.)</u>

A	B	C	D	1.	Philosophy of research
A	B	C	D	2.	Use of scientific method to solve problems
A	B	C	D	3.	Use of experimental checks and controls
A	B	C	D	4.	Measurement techniques
A	B	C	D	5.	Design of equipment
A	B	C	D	6.	Calibration of reagents, standards, and instruments
A	B	C	D	7.	Process of design of an experiment
A	B	C	D	8.	Data analysis (with or without computer assistance)
A	B	C	D	9.	Computer programming
A	B	C	D	10.	Acquisition and use of scientific literature (books, audio visual)
A	B	C	D	11.	Identification of new questions as a consequence of scientific exploration
A	B	C	D	12.	Teamwork in scientific research
A	B	C	D	13.	Use of advanced scientific equipment
A	B	C	D	14.	Other students with similar interests and goals
A	B	C	D	15.	Scientists working in different areas of research
A	B	C	D	16.	Information on scientific careers

II. How much has your experience as an apprentice contributed to your development in each of the following? (Circle one letter per line)

A B C D 1. Working with adults

A B C D 2. Responsibility on a job

A B C D 3. Understanding of scientific principles

A B C D 4. Scientific vocabulary

A B C D 5. Ability to write a technical report

A B C D 6. Understanding of your interests and abilities

A B C D 7. Educational goal setting

A B C D 8. Insights into career opportunities in science

A B C D 9. Career goal setting

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL
E = NOT AVAILABLE/
NOT RELEVANT)

III. To what extent did you benefit from the following?

A B C D E 1. Planned lectures or seminars

A B C D E 2. Explanations of work by mentor

A B C D E 3. Tours of other laboratories or installations

A B C D E 4. Informal talks with mentor

A B C D E 5. Discussions with other scientists

A B C D E 6. Interactions with other apprentices

A B C D E 7. Advice from the program coordinator

(A = STRONGLY AGREE

B = AGREE
C = DISAGREE
D = STRONGLY DISAGREE)

IV. How do you feel about your research apprentice experience?

A B C D 1. I enjoyed the experience

A B C D 2. I liked the scientific research

A B C D 3. I was satisfied with the way I spent my time

A B C D 4. I learned a lot

A B C D 5. I feel I contributed to the research results

V. Would you want to return to the same mentor next year?

o Yes o No: If No, why?

- o personality conflicts
- o lack of interest
- o want a different experience
- o want a different location

VI. What did you like most about the program?

VII. What did you like least about the program?

DO NOT SIGN

RETURN FORM TO YOUR COORDINATOR BY 14 September 1990
date

Susan Espy
Name of Coordinator

Universal Energy Systems
4401 Dayton-Xenia Rd.
Dayton, OH 45432
Address

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
APPRENTICE EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A HIGH SCHOOL STUDENT)

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL)

I. How much were you exposed to each of the following during your summer apprenticeship? (Circle one letter per line.)

A	B	C	D		
46	27	26	6	1.	Philosophy of research
36	35	26	8	2.	Use of scientific method to solve problems
45	23	26	11	3.	Use of experimental checks and controls
42	26	18	19	4.	Measurement techniques
38	30	24	13	5.	Design of equipment
30	20	20	35	6.	Calibration of reagents, standards, and instruments
39	31	19	44	7.	Process of design of an experiment
80	17	6	2	8.	Data analysis (with or without computer assistance)
65	17	11	13	9.	Computer programming
47	28	22	8	10.	Acquisition and use of scientific literature (books, audio visual)
34	44	18	9	11.	Identification of new questions as a consequence of scientific exploration
62	30	9	4	12.	Teamwork in scientific research
61	26	11	7	13.	Use of advanced scientific equipment
34	29	26	16	14.	Other students with similar interests and goals
51	29	17	7	15.	Scientists working in different areas of research
48	33	20	4	16.	Information on scientific careers

II. How much has your experience as an apprentice contributed to your development in each of the following? (Circle one letter per line)

A	B	C	D	
77	21	7	0	1. Working with adults
68	27	10	0	2. Responsibility on a job
46	34	22	3	3. Understanding of scientific principles
57	27	16	5	4. Scientific vocabulary
33	46	19	7	5. Ability to write a technical report
65	30	10	0	6. Understanding of your interests and abilities
55	33	14	3	7. Educational goal setting
60	29	13	3	8. Insights into career opportunities in science
51	33	19	2	9. Career goal setting

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL
E = NOT AVAILABLE/
NOT RELEVANT)

III. To what extent did you benefit from the following?

A	B	C	D	E	
15	19	21	2	48	1. Planned lectures or seminars
73	22	5	4	1	2. Explanations of work by mentor
27	28	22	5	23	3. Tours of other laboratories or installations
73	19	7	5	1	4. Informal talks with mentor
59	27	14	2	3	5. Discussions with other scientists
36	19	22	10	18	6. Interactions with other apprentices
16	22	25	18	24	7. Advice from the program coordinator

(A = STRONGLY AGREE
B = AGREE
C = DISAGREE
D = STRONGLY DISAGREE)

A	B	C	D		IV. How do you feel about your research apprentice experience?
79	22	4	0	1.	I enjoyed the experience
59	37	3	6	2.	I liked the scientific research
51	41	10	3	3.	I was satisfied with the way I spent my time
73	25	6	1	4.	I learned a lot
55	37	5	7	5.	I feel I contributed to the research results

V. Would you want to return to the same mentor next year?

72 Yes   31 No: If No, why?

1	personality conflicts
5	lack of interest
23	want a different experience
10	want a different location

VI. What did you like most about the program?

35 of the students thought that the mentor and the various people in the laboratory was what they liked the most about the program. They commented that they were treated as adults and not as high school students, that what they thought or accomplished was important. 29 of the students liked the exposure to a work atmosphere. The students were very thankful to have the opportunity to work beside scientist and engineers doing real research. Another comment was that the equipment, laboratories, and computers are what 19 of the students liked the most. Eleven of the students liked the project that they were assigned to, and the learning experience that they had. A few students expressed that before they received the position that they had not decided on a career, but 8 students have now due to the program. Five of the students liked the different employment opportunities that are available, while 2 of the students liked learning more about the Air Force and the opportunities that they have available.

VII. What did you like least about the program?

The majority of what the students liked least was that the program was not long enough. The 12 responses indicated that the program should be lengthened to 10 to 12 weeks. Eleven of the students commented at they were not keep busy. The mentors did not either have the time to spend with them, or the students finished the projects that the mentors had assigned. Six of the students disliked writing a final report at the end of the summer. While another six students thought the pay should be higher considering the type of work they were doing. Five of the students commented that they did not do the project that was originally discussed once they got there. Another five students least liked the timecards and there schedule, also the delay in getting their paychecks. Four students responded that their mentors were TDY and was not available for most of the summer. Four other students commented that they did not get along with the people in labs, that they were treated like "gofers" and doing errands, and office work. Another 4 students disliked the project they were doing, some of the comments were that they did not think it was real research but "busy work". Other comments consisted of no sick or holiday pay, lack of information about UES, no positions available for college students, getting up early, lack of air conditioning, and even that the water tasted funny.

DO NOT SIGN

RETURN FORM TO YOUR COORDINATOR BY 14 September 1990
date

Susan Espy
Name of Coordinator

Universal Energy Systems
4401 Dayton-Xenia Rd.
Dayton, OH 45432
Address
2361s

LIST OF PARTICIPANTS FINAL REPORTS

RESEARCH REPORTS

1990 HIGH SCHOOL APPRENTICESHIP PROGRAM

Technical Report Number	Title	Participant
VOLUME I		
Aero Propulsion Laboratory		
1	Flash Plate Evaporator	Matthew Bold
2	Frozen Start Up	Hee Sun Choung
3	Nonaqueous Battery Research	Katharine Day
4	Setup Tecplot	Chris Hatch
5	Flash Plate Evaporator	Chet Nieter
6	Final Report to UES	Jennifer Pollock
7	Frozen Start Up	Carol Rogers
Armament Laboratory		
8	Wind Velocimeters for Calculating Ballistic Trajectories	Steven Bryan
9	Star Availability for Sensor - Specific Evaluation (S.A.S.S.E.)	Tonya Cook
10	Development of a Customized Database System for the Distribution of EPIC Hydrocode Software	Heather Cox
11	Synthesis and Characterization of 3-Picrylamino-1,2,4-Triazole	Kathryn Deibler
12	Neural Target Identification	Chris Ellis
13	Space Debris Analysis	Dana Farver
14	Enhancement and Integration of Post Process Utilities for the EPIC Hydrocodes	Kenneth Gage
15	Design of In-House Radar Control and Data Acquisition Systems	Reid Harrison
16	1990 HSAP Final Event Summary	Derek Holland

35	Program Final Report	Jason Scott
36	Real-Time Radiography Ray Tracing	Gerald Turner
Astronautics Laboratory		
37	The Summer in Review	Alisha Conrow
38	Synthesis of Two Cage Compounds	Debra Meyer
39	Fundamental Rocket Exhaust Measurements	John Moro
40	Analytic Predictions of Hydroxy-terminated Polybutadiene (HTPB) Modulus using Random Iterative Discrete Node Algorithm (RIDNA)	Lloyd Neurauter
41	Liquid Engine Computer Codes	Joseph Padilla
42	Determination of Active Surface Area and Density of Carbons	Melanie Pyle
43	No Report Submitted	Thomas Quinn
44	High School Apprenticeship Program Final Report	Tracy Reed
45	1990 Final Report	Benjamin Sommers
46	No Report Submitted	Stephanie VanMeter
47	A Comparison of Electric Propulsion Orbit Transfer Methods	Rebecca Weston
48	No Report Submitted	David Youmans
Avionics Laboratory		
49	Ada Compiler Evaluation Capability Testing Utility (ACEC)	Brian Barclay
50	Pattern Based Machine Learning	Mark Boeke
51	Pattern Based Machine Learning: A Comparison of ADA Function Decomposer Versions	Michael Chabinyc
52	Computer Simulation of SDI	David Collins
53	Final Report Summer 1990	Austin Flack
54	No Report Submitted	Jerard Wilson

Engineering and Services Center

VOLUME III
Electronic Technology Laboratory

Flight Dynamics Laboratory

75	High School Apprenticeship Program Final Report	Jean Ay
76	Project "Environmental Reliability": The Analysis of Printed Circuit boards	Matthew Becker
77	High Speed Performance Computer Resources Team	Wendy Choate
78	No Report Submitted	Andrea Dean
79	Leading Edge Heat Exchanger	Rachael Lyon
80	Final Report for Cathie Moore	Cathie Moore
81	Project Instrumentation	Roderick Morgan
82	ENTRAN Manual	Stanley Wall
83	Final Report	Douglas Wickert

Geophysics Laboratory

84	Determining Tropical Storm Direction of Movement Using SSM/I Brightness Temperature Data	Stephen Britten
85	Auroral Boundaries	Weihaw Chuang
86	Mesoscale Modeling	Christopher Guild
87	No Report Submitted	Jason Klingensmith
88	Solar Terrestrial Interactions	Galen McKinley
89	Ionospheric Effects	Jeffrey Sayasane
90	Final Report	Paul Swietek

Materials Laboratory

91	Fatigue of Composites	Jennifer Walker

Occupational and Environmental Health Laboratory

92	Automated Heat Stress Measurements	Gary New
93	Compilation of Hazardous Waste Surveys	Andrea Dean (Perez)
94	Automation of Water Analysis	Michael Smid

Rome Air Development Center

95	Pre-Commissioning and Capabilities of the Workhorse Scatterometer: A Final Report	Daniel Abbis
96	No Report Submitted	Mark Anania
97	Radar Range Equation and Radar Design and Simulation	Bridget Bordiuk
98	No Report Submitted	Todd Gleason
99	Cartographic Applications	Christopher Hailes
100	Application Software Development for use on Directory Specific Network	Edward Holmes
101	Various Projects in Data Analysis of Surveillance Systems	Kimberly King
102	Network Processing Element Test and Evaluation	Kathryn Lee
103	Gemacs Version 5.0 Modifications and Applications	Jason Lenio
104	Activities at RADC Photonics Lab	Kevin Olson
105	Overview of Neural Networks	David Petrillo
106	Surface Analysis	Thomas Potter
107	Software Inventory Control System Database	Daniel Russell
108	Artificial Neural Networks	Philip Schremmer
109	Local Area Networks	Eric Shaw

VOLUME IV
School of Aerospace Medicine

110	No Report Submitted	Anthony Barnes
111	Final Report	Whitney Brandt
112	Preliminary Testing of an Inert Gas Concentrator Using Carbon Molecular Sieve	Deann Cooper
113	Affects of Anti-G Straining Maneuvers on Blood Pressures in Man; Affects of +Gz on the Cardiovascular System of Baboons	Matthew Felder

114	Apolipoprotein Comparison Study and CAD Prediction Study	Christopher Hudson
115	High School Apprenticeship Program Final Report	Soyna Longbotham
116	Determination of Optimum Growth and Strain Facilities for Diazotyrosine Production	Brian McBurnett
117	Serum Factor - Induced Expression of the C-FOS Gene in NIH 3T3 Cells	Heather Neville
118	Biological Rhythms Research	Lori Olenick
119	Report on File with UES & SAM	Joanna Saucedo
120	Medical Entomology Activities	Wendy Shields
121	Establishing High and Low Rate Operant Behavior in Rats	Brent Strawn
122	UES Report	John Taboada

Weapons Laboratory

123	Phase Conjugation and Beam Coupling	David Cochrell
124	Final Report	Paul Hillman
125	A Study in C	David Knapp
126	Final Report of Summer Mentor	Aaron Laing
127	Statistical Analysis of Cone Penetrometer Data	Kerim Martinez
128	No Report Submitted	Ryan McAlhaney
129	Microwave Susceptibility Testing of Micro-Circuitry	Margaret Morecock
130	Construction of a Delay Circuit for Data Acquisition Coordination	Philip Ortiz
131	Contour Plots	Brian Rizzoli
132	Wide Bandwidth Crosslink Register Technical Report	Chris Stoltenberg

FINAL REPORTS

ELECTRONIC TECHNOLOGY LABORATORY

Matt Brewer

Mark Calcatera

Avionics Laboratory

August 10, 1990

During my apprenticeship this summer, I had the opportunity to work on many different computer systems in the lab. These systems are used by the engineers to design and simulate microwave circuits. The results of these simulations could then be used to modify the circuit so that when it finally went to processing, it is in its best possible form.

I performed various tasks on the computers to assist the engineers in their various tasks. These jobs included entering microwave circuit designs, simulating designs, writing element models for design programs, et al. My work on the different systems allowed the engineers more time for their tasks, while allowing me the chance to work on state of the art computer equipment and gain practical programming and CAD related skills.

My work here will have many different applications. My work on the HP design system will factor into decision on whether or not to purchase that product. My design and simulation work will help to further tasks as they go from the design to the processing stage. Finally, the element models I have helped to code while allow for more accurate simulation of microwave circuits.

My first task was to work on the HP 85150B Microwave Design System. This system was on loan from Hewlett-Packard because the lab was considering purchasing it. My task was to figure out the operating system, sort though the manuals, and learn to run the machine so that the engineers could enter their circuit designs and see how well it actually worked.

I started off by going through the manuals and entering their example circuits. This worked out pretty well and gave me a general idea of how the machine worked. Next, I started to simulate my own simple circuits. This was a good function because I knew what the answers were suppose to be, all I had to do was make the machine give me the right answers. Then, I went to more advanced circuits, such as RC-circuits. This gave me a chance to learn the output functions; like listing charts, rectangular plots, polar graphs, Smith Chart graphs, etc..

Once I was familiar with the system, I began to enter actual circuits for the engineers. Mark had many different circuits to simulate, the first was a transistor. To simulate this circuit, I would first need to lay out the schematic. This would involve getting elements from the menus (e.g. resistors, capacitors, etc.) and connecting them properly. Then I would have to set up a simulation parameter block. This block would tell the computer what frequency range to sweep over, how many points to plot, and other pertinent data. Then I would run the simulator. After simulation, data could be viewed in a number of different forms (fig. 1 & 2). Mark could then go back and make changes in the

circuit based on this output.

Next I simulated four different spiral inductors. They all were similar but had different parameters. I entered the schematic for each one, set up the simulation block, and simulated them. The simulations worked but not as we expected. These particular spiral inductors had half turns, but the simulator allowed for only an integer number of turns. This caused a real problem because, in the actual circuit processing, it is easier to make a fraction of a turn spiral inductor than it is a whole number turn spiral inductor. We were going to compare the spiral inductor simulated data with actual observed data from processed circuit, but since we couldn't we left the spiral inductors on hold.

I then simulated two groups of elements for Lois, another engineer in the microwave lab. The first group was four thin film capacitors. They were all similar but had different parameters. I entered the schematics, set up the parameter block and simulated the four capacitors. The capacitor results weren't good at all. The HP simulator wouldn't let the dielectric thickness of the thin film capacitor go as thin as it needed to. The limit set by the programmers made the dielectric have a minimum thickness with respect to the electrode length and width. This meant the thin film capacitors processed right here on the base couldn't be simulated at all on the HP system.

The second group of elements I simulated for Lois was a group

of microstrip elements. This was done to compare the HP results with those of other design systems, such as Libra and Super Compact. I entered the schematics for two microstrip lines of varying lengths and a microstrip tee junction. The schematics were then simulated and the results were displayed in tabular form to be compared with the results from the other system . The results of the microstrip element simulations went very well and came out much as Lois had expected.

I spent three weeks on the HP system. It went back to Hewlett-Packard on July sixth. The decision on whether or not to buy the HP system hasn't been made yet. but hopefully my work on that machine helped make the decision a wise one.

My next task was to work on Super Compact. This program is on the Vax system. I had to receive a Vax account to have access to these programs. After I received my vax account, I tried simulating sample circuits found in the Super Compact manuals. In Super Compact you have to create a net list of all the different circuit elements in a circuit block. Then, other blocks must be added such as frequency blocks, dimension blocks, output blocks, et al.. Then the simulation is done and the plots are displayed as called for in the output block.

After learning to use the system, I did two different simulations for Misson, another engineer in the microwave lab. The two designs were a C-Band PAC2-3D Amplifier and a X-Band Low Noise Amplifier. Both of the amplifiers were simulated on the Super

Compact system. The C-Band amplifier was never pursued by Misson, but the X-Band amplifier was of interest. The X-Band amplifier was entered into Super Compact from the schematic, to a net list, and finally into program form (Appendix 1 contains the X-Band Low Noise Amplifier in Super Compact code).

After the simulation, I plotted out S11 (fig.3), S21 (fig.4), and S22 (fig.5). After evaluating the plots, Missoon had me replace the transistor that was in the original circuit with those of an in-house processed FET. I had to add an S-parameter data file and the proper procedural calls to simulate the FET. Next, I added a noise block to simulate the noise added to circuit by the FET. This was a syntax problem because the program not supposed to allow noise blocks for three port devices. With the help of Phil Mumford and Rick Worley, I was able to make it work.

Now, with all the data in place, it was time to optimize the circuit. Before we could optimize, we had to figure out what variables could be easily changed and what values were most important. Missoon determined that the lengths of the microstrip lines could be most easily changed, and the widths could be varied if needed. Then the parameters to be optimized were chosen. Stability was most important. High gain and low noise were also necessary, and low reflection was needed.

With these factors in mind, I added an optimization block to

the circuit and marked the variables to be changed. I employed both the optimization techniques available on the Super Compact system. The random optimizer was most useful at first. This type of optimization allows each variable to change randomly, and records the best results. This can be used to get a rough idea of the best design. From there, I used a gradient optimizer. It allows the variables to change a little at a time and zeros in on the lowest error. Appendix 2 contains the completed X-Band Low Noise Amplifier.

With the optimization complete, the simulation part of the circuit design is done. The X-Band Low Noise Amplifier can now be laid out for processing on a system such as the Calma. The amplifier may be incorporated in the Mimmic 3 mask set which is under design now.

The last task I worked on was creating user defined models on the Libra design system. This first involved developing equations for the S-parameters of the element that needed to be simulated. The element we chose to model first was a resistive attenuator, because it was simple and EEsof had already prepared equations for it. Our goal was to model a spiral inductor but time did not allow it. The equations used are as follows:

YA1=1.0/R3+1.0/zo (1)

ZA1=1.0/YA1 (2)

ZB1=R2+ZA1 (3)

YA2=1.0/R1+1.0/zo (4)

ZA2=1.0/YA2 (5)

ZB2=R2+ZA2 (6)

Z1=(R1*ZB1)/(R1+ZB1) (7)

Z2=(R3*ZB2)/(R3+ZB2) (8)

S11=(Z1-zo)/(Z1+zo) (9)

S22=(Z2-zo)/(Z2+zo) (10)

S12=S21=(2.0/zo)/(1.0/ZA+1.0/ZA2+R2/(ZA1*ZA2)) (11)

With the equations prepared, my next task was to code, in C, a procedure to be incorporated into the existing program. I copied the EEsof code into my directory and edited it and inserted the attenuator equations. Next I had to copy the existing Libra library into my directory. Then I compiled my code using the following command:

```
CC/OBJ=USERPROC USERPROC.ABC
```

USERPROC.XMP was the skeleton source code and USERPROC.ABC was my modified code. Then I had to link the USERPROC.C code to the existing Libra library. This was a big task, but EEsof prepared a link command for us (they just weren't nice enough to tell us that). After copying Link_Libra into my directory, I linked the code with this command:

```
LINK_LIBRA
```

When this was completed I had an executable version of Libra in my user directory.

However, because of the licensing agreement with EEsof. Libra

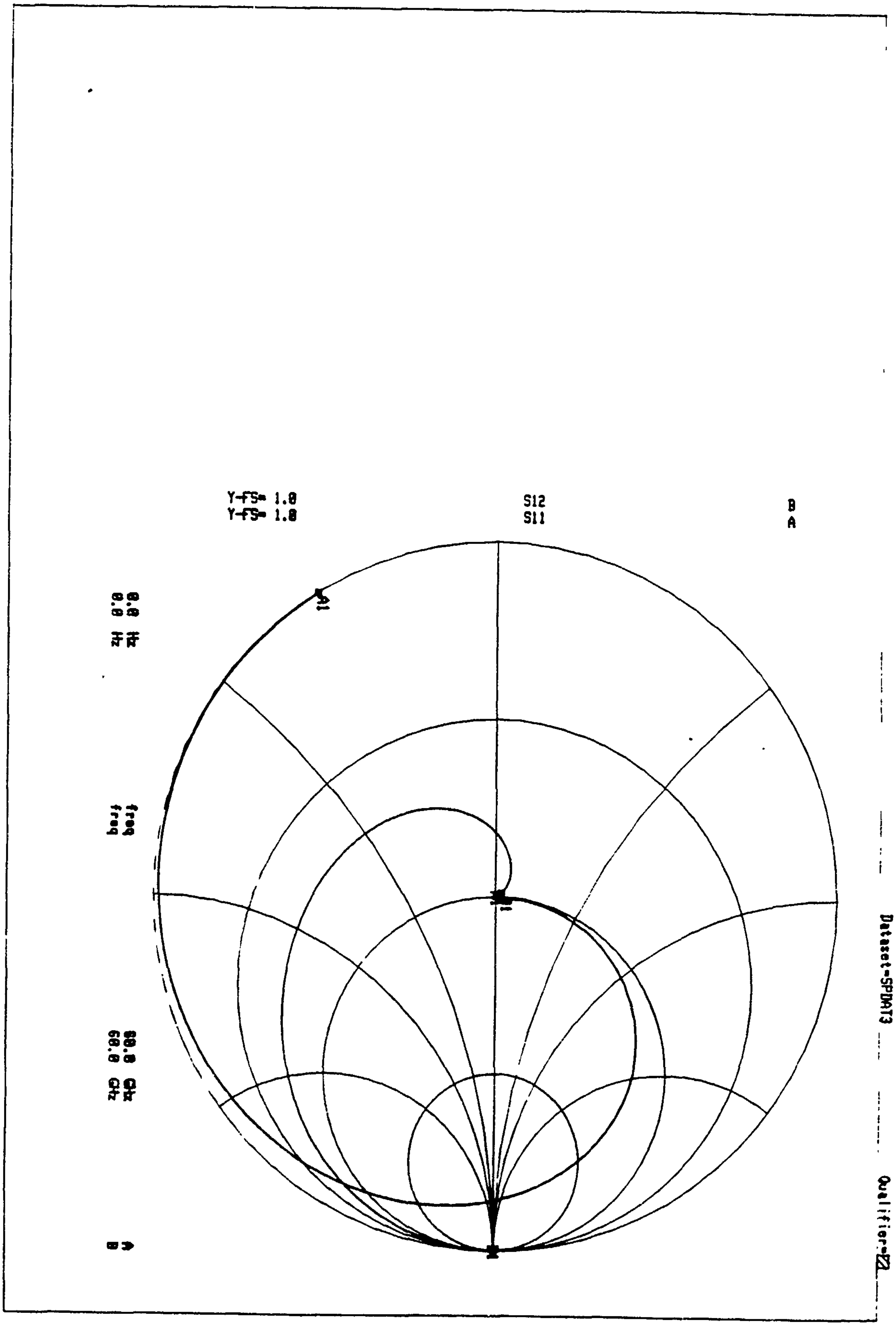
is only a single user item. For the same reason, we were only allowed to have one working version of Libra running at one time. So, my file wouldn't work because of the system file. So, I had to get Ben Carroll to go into my account from the system manager level and install the Libra in my account with SYSLCK (System Lock) privileges. What that did was to allow me to run my program by locking out the system Libra, but when I wasn't working the system Libra would be running.

Once this was done I was able to run the Libra in my directory. I then began debugging the code. The documentation was out of date and I had to hack through it. First, I had to add the function name to the list of local declarations. Second, was changing the number of user elements from zero to one. Adding a new user element to the field of elements was the next task. Last, I modified the userkey array to add a new keyword. These changes, in addition to the code I had already written, allowed me to execute the code.

The problems however weren't completely solved. When I tried to use the attenuator in a circuit, Libra told me I had an improperly handled situation, core dumped, and booted out of simulation. To figure out the problem, I to do several things. I first converted the hex numbers to decimal. Then I went back through the audit file to find what line of code was in that decimal memory location when the program crashed. I looked at that line and found I had left an ampersand out of a procedural call.

With the problem solved, I had a working model for a resistive attenuator. Although I didn't have enough time to complete the task of modeling a spiral inductor, this code will serve as an outline for anyone who wants to continue the job. They will just have to add to my user code and recompile the executable file. Appendix C contains my completed procedure for the resistive attenuator.

Fig. 1



cmp5.SP table:

Variable	Format	EOF	Wrt	Max	X Min	X Max	Y Min	Y Max
KEY1	INT	121	121	121	1	121		
S[1,1]	L RI	121	121	121	-.852E+00	.871E+00	-.986E+00	.414E+00
S[1,2]	L RI	121	121	121	-.248E+00	.1000E+01	-.621E+00	.453E-01
S[2,1]	L RI	121	121	121	-.248E+00	.1000E+01	-.621E+00	.453E-01
S[2,2]	L RI	121	121	121	-.872E+00	.851E+00	-.982E+00	.393E+00
PORTZ[1]	L RI	121	121	121	.500E+02	.500E+02	.000E+00	.000E+00
PORTZ[2]	L RI	121	121	121	.500E+02	.500E+02	.000E+00	.000E+00

Fig. 2

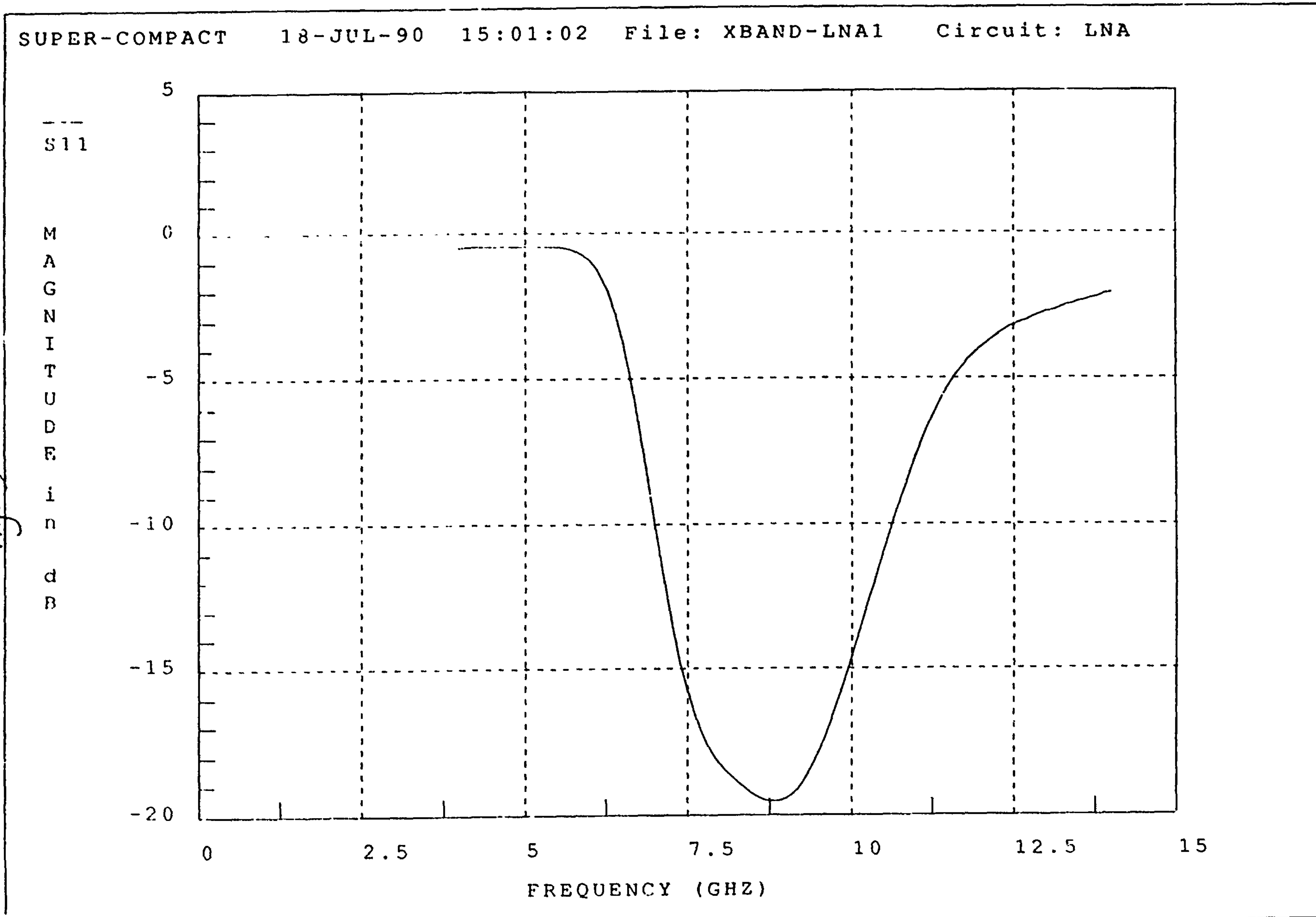

SUPER-COMPACT 18-JUL-90 15:01:02 File: XBAND-LNA1 Circuit: LNA
S11
MAGNITUDE in dB
5
0
-5
-10
-15
-20
0
2.5
5
7.5
10
12.5
15
FREQUENCY (GHZ)

Fig. 3

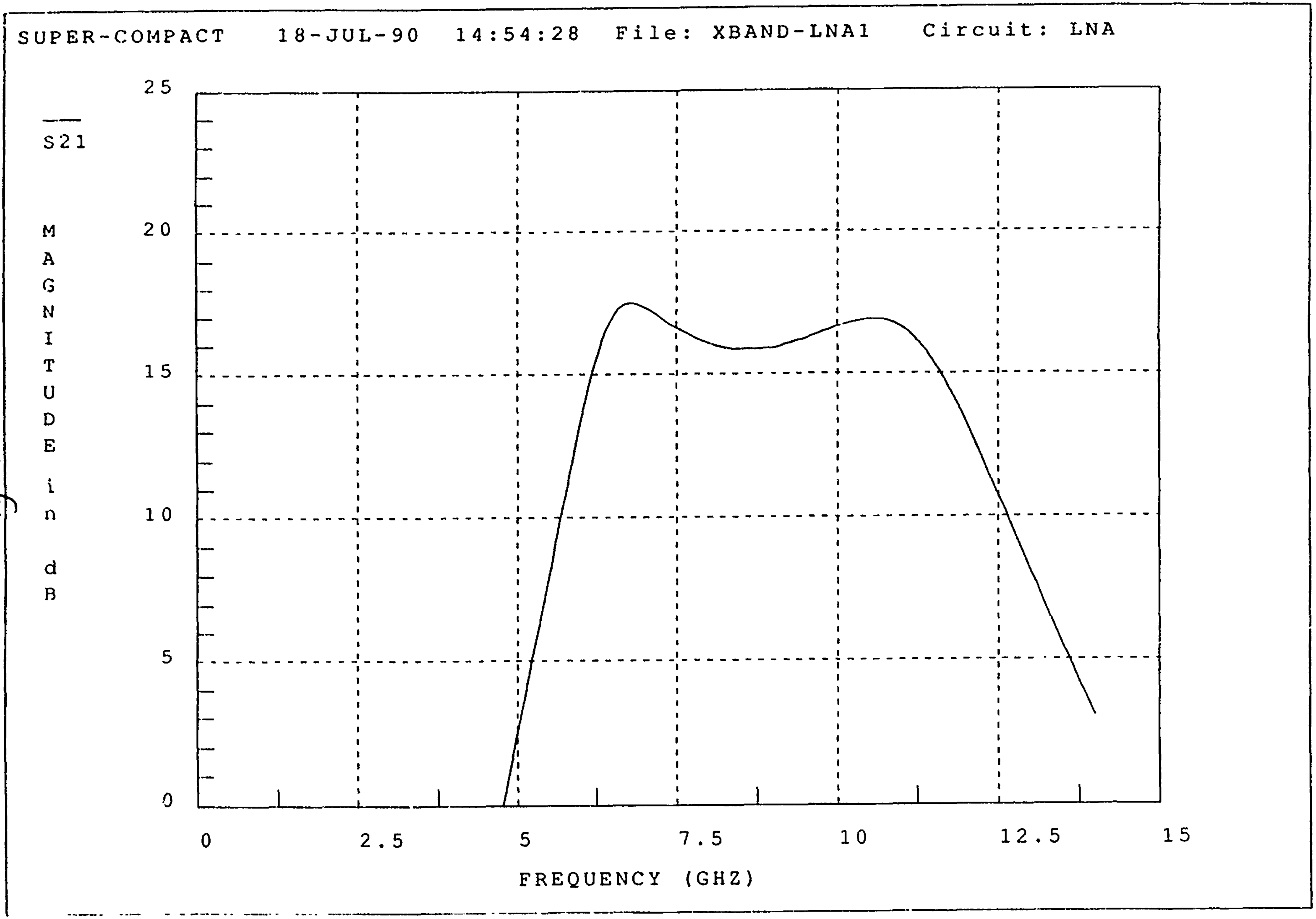

SUPER-COMPACT 18-JUL-90 14:54:28 File: XBAND-LNA1 Circuit: LNA
S21
MAGNITUDE in dB
25
20
15
10
5
0
0
2.5
5
7.5
10
12.5
15
FREQUENCY (GHZ)

Fig 4

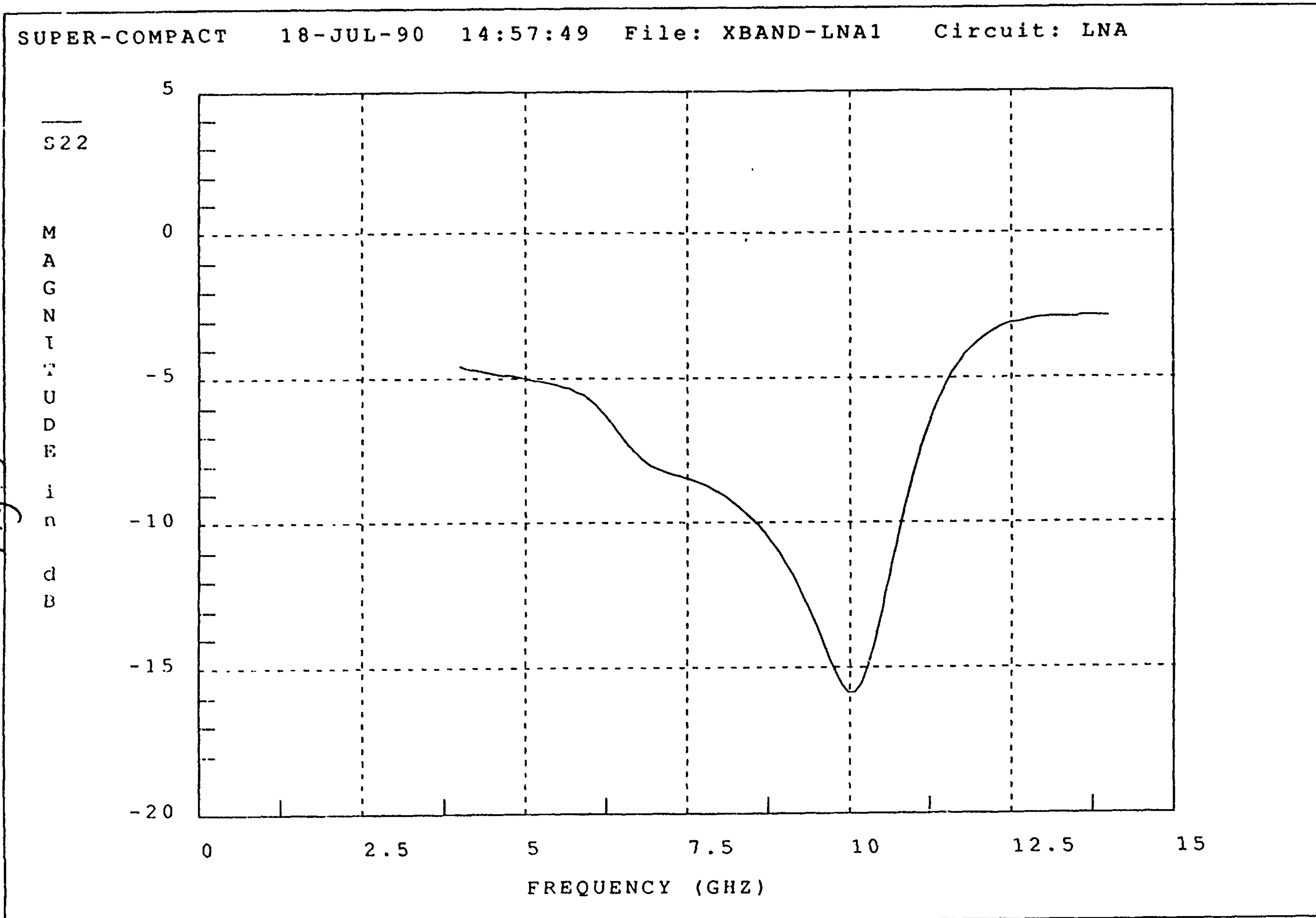

SUPER-COMPACT 18-JUL-90 14:57:49 File: XBAND-LNA1 Circuit: LNA
S22
MAGNITUDE in dB
5
0
-5
-10
-15
-20
0
2.5
5
7.5
10
12.5
15
FREQUENCY (GHZ)

Fig. 5

APPENDIX 1

```
* HARRIS 2-STAGE LNA REDESIGN USING NEW TOPOLOGY AND LOSSY OUTPUT
* MATCHING...SPECS...BANDWIDTH 7.0-11.0 GHZ...GAIN=16.0DB+/-0.5DB
* ...N.F.<2.5DB...INPUT AND OUTPUT RETURN LOSS <15DB...
*

****************************VARIABLES***************************

CDUMMY      :1PF
LSFBA       :450UM
LSFBB       :450UM

WC1         :32UM
L10         :900UM
L11         :780UM
L12         :1000UM
L13         :570UM

L21         :1500UM
L22         :750UM
RGATE       :200UM
L23         :450UM

L31         :700UM
L32         :1600UM
L33         :600UM
RCOMP       :50UM
L34         :1600UM

BLK
  JUMP 1 2 W=20UM T=0UM L=10UM SUB
  STEP 2 3 W1=20UM W2=192UM SUB
  TRL 3 4 W=192UM P=192UM SUB
  CAP 4 5 C=10PF Q=30 F=11.5GHZ
  IND 5 6 L=.015NH
  CAP10:2POR 1 6
END

BLK
  STEP 9 1 W1=20UM W2=130UM SUB
  TRL 1 2 W=130UM P=130UM SUB
  CAP 2 3 C=4.6PF Q=30 F=11.5GHZ
  STEP 3 4 W1=130UM W2=20UM SUB
  JUMP 4 5 W=20UM T=0UM L=10UM SUB
  CAP5:2POR 9 5
END

BLK
  STEP 9 1 W1=30UM W2=WC1 SUB
  TRL 1 2 W=WC1 P=WC1 SUB
  CAP 2 3 C=(CDUMMY*32*32/3676.50) q=30 F=11.5GHZ
  STEP 3 4 W1=WC1 W2=WC1 SUB
  JUMP 4 5 W=35UM T=0UM L=10UM SUB
```

```
  IND 5 6 L=.030NH
  CAP2:2POR 9 6
END

BLK
  TWO 1 2 3 D1
  NA2P:3POR 1 2 3
END

BLK
  TRL 1 3 W=23UM P=LSFBA SUB
  TRL 1 2 W=25UM P=LSFBA SUB
  CAP10 3 0
  CAP10 2 0
  NASER:1POR 1
END

BLK
  IND 1 2 L=.2NH
  TRL 2 3 W=88UM P=88UM SUB
  CAP5 3 4
  CROS 4 10 11 12 W1=88UM W2=40UM W3=20UM W4=40UM SUB
  OST 10 W=40UM P=L10 SUB
  OST 12 W=40UM P=L10 SUB
  TRL 11 5 W=20UM P=L11 SUB
  TEE 5 6 7 W1=20UM W2=20UM W3=20UM SUB
  SST 7 W=20UM P=L12 SUB
  TRL 6 8 W=20UM P=L13 SUB
  NAIN:2POR 1 8
END

BLK
  TWO 1 2 3 D2
  NB2P:3POR 1 2 3
END

BLK
  TRL 1 3 W=25UM P=LSFBB SUB
  TRL 1 2 W=25UM P=LSFBB SUB
  CAP10 3 0
  CAP10 2 0
  NBSER:1POR 1
END

BLK
  TRL 1 2 W=20UM P=L21 SUB
  TEE 2 4 3 W1=20UM W2=20UM W3=130UM SUB
  TRL 4 5 W=20UM P=L22 SUB
  CAP10 5 0
  CAP5 3 6
  TFR 6 10 W=20UM P=40UM RS=100 SUB
  SST 10 W=20UM P=600UM SUB
  TRL 6 7 W=20UM P=L23 SUB
  NBIN:2POR 1 7
END
```

```
BLK
  TRL 1 2 W=20UM P=L31 SUB
  TEE 3 4 2 W1=20UM W2=20UM W3=20UM SUB
  TRL 4 5 W=20UM P=L32 SUB
  CAP10 5 0
  TRL 3 6 W=20UM P=L33 SUB
  TFR 6 7 W=40UM P=20UM RS=100 SUB
  TRL 7 8W=20UM P=L34 SUB
  CAP10 8 0
  CAP5 6 9
  TRL 9 10 W=88UM P=88UM SUB
  IND 10 11 L=.2NH
  NBOUT:2POR 1 11
END

BLK
  NAIN 1 2
  NA2P 2 3 4
  NASER 4 0
  NBIN 3 5
  NB2P 5 6 7
  NBSER 7 0
  NBOUT 6 8
  LNA:2POR 1 8
END

FREQ
  STEP 4GHZ 14GHZ .10GHZ
END

OUT
  PLO LNA S
END

DATA
  *SUBSTRATE DATA
   SUB:MS H=125UM ER=12.9 TAND=.0001 MET1=AU 3.4UM
  *S-PARAMETER DATA
   D1:H300 FILE=H300.DAT
   D2:H300 FILE=H300.DAT
END
```

APPENDIX 2

```
* HARRIS 2-STAGE LNA REDESIGN USING NEW TOPOLOGY AND LOSSY OUTPUT
* MATCHING...SPECS...BANDWIDTH 7.0-11.0 GHZ...GAIN=16.0DB+/-0.5DB
* ...N.F.<2.5DB...INPUT AND OUTPUT RETURN LOSS <15DB...
*

*****************************VARIABLES****************************

CDUMMY      :1PF
LSFBA       :37.172UM
LSFBB       :65.489UM

WC1         :32UM
L10         :609.74UM
L11         :827.55UM
L12         :925.56UM
L13         :294.52UM

L21         :1583.1UM
L22         :543.67UM
RGATE       :200UM
L23         :504.98UM

L31         :1087UM
L32         :1434.1UM
L33         :150.88UM
RCOMP       :50UM
L34         :2472.9UM

BLK
  JUMP 1 2 W=20UM T=0UM L=10UM SUB
  STEP 2 3 W1=20UM W2=192UM SUB
  TRL 3 4 W=192UM P=192UM SUB
  CAP 4 5 C=10PF Q=30 F=11.5GHZ
  IND 5 6 L=.015NH
  CAP10:2POR 1 6
END

BLK
  STEP 9 1 W1=20UM W2=130UM SUB
  TRL 1 2 W=130UM P=130UM SUB
  CAP 2 3 C=4.6PF Q=30 F=11.5GHZ
  STEP 3 4 W1=130UM W2=20UM SUB
  JUMP 4 5 W=20UM T=0UM L=10UM SUB
  CAP5:2POR 9 5
END

BLK
  STEP 9 1 W1=30UM W2=WC1 SUB
  TRL 1 2 W=WC1 P=WC1 SUB
  CAP 2 3 C=(CDUMMY*32*32/3676.50) q=30 F=11.5GHZ
```

```
  STEP 3   W1=WC1 W2=WC1 SUB
  JUMP 4 5 W=35UM T=0UM L=10UM SUB
  IND 5 6 L=.030NH
  CAP2:2POR 9 6
END

BLK
  TRL 1 3 W=23UM P=LSFBA SUB
  TRL 1 2 W=25UM P=LSFBA SUB
  CAP10 3 0
  CAP10 2 0
  NASER:1POR 1
END

BLK
  IND 1 2 L=.2NH
  TRL 2 3 W=88UM P=88UM SUB
  CAP5 3 4
  CROS 4 10 11 12 W1=88UM W2=40UM W3=20UM W4=40UM SUB
  OST 10 W=40UM P=L10 SUB
  OST 12 W=40UM P=L10 SUB
  TRL 11 5 W=20UM P=L11 SUB
  TEE 5 6 7 W1=20UM W2=20UM W3=20UM SUB
  SST 7 W=20UM P=L12 SUB
  TRL 6 8 W=20UM P=L13 SUB
  NAIN:2POR 1 8
END

BLK
  TRL 1 3 W=25UM P=LSFBB SUB
  TRL 1 2 W=25UM P=LSFBB SUB
  CAP10 3 0
  CAP10 2 0
  NBSER:1POR 1
END

BLK
  TRL 1 2 W=20UM P=L21 SUB
  TEE 2 4 3 W1=20UM W2=20UM W3=130UM SUB
  TRL 4 5 W=20UM P=L22 SUB
  CAP10 5 0
  CAP5 3 6
  TFR 6 10 W=20UM P=40UM RS=100 SUB
  SST 10 W=20UM P=600UM SUB
  TRL 6 7 W=20UM P=L23 SUB
  NBIN:2POR 1 7
END

BLK
  TRL 1 2 W=20UM P=L31 SUB
  TEE 3 4 2 W1=20UM W2=20UM W3=20UM SUB
  TRL 4 5 W=20UM P=L32 SUB
  CAP10 5 0
  TRL 3 6 W=20UM P=L33 SUB
```

```
  TFR 6 7 W=40UM P=20UM RS=100 SUB
  TRL 7 8W=20UM P=L34 SUB
  CAP10 8 0
  CAP5 6 9
  TRL 9 10 W=88UM P=88UM SUB
  IND 10 11 L=.2NH
  NBOUT:2POR 1 11
END

BLK
  TWO 1 2 3 D1
  NASER 3 0
  PRE1:2POR 1 2
END

BLK
  NAIN 1 2
  PRE1 2 3
  NBIN 3 4
  NBSER 6 0
  NBOUT 5 7
  LNA:2POR 1 7
END

FREQ
  STEP 4GHZ 14GHZ .10GHZ
END

OPT
   LNA F=6GHZ 12GHZ K=1 GT W=1000
   LNA F=6GHZ 11GHZ NF=2.5 LT W=100
   LNA F=7GHZ 11.5GHZ MS21=17.0 GT W=100
   LNA F=7GHZ 11.5GHZ MS21=18.0 LT W=200
   LNA F=10GHZ 11.5GHZ MS21=17.0 GT W=400
   LNA F=7.5GHZ 10.5GHZ MS11=-15 LT W=20 MS22=-12 LT W=10
END

OUT
  PLO LNA S
END

DATA
  *SUBSTRATE DATA
   SUB:MS H=125UM ER=12.9 TAND=.0001 MET1=AU 3.4UM
  *S-PARAMETER DATA
   D1:H300 FILE=H300.DAT
   D2:H300 FILE=H300.DAT
  *NOISE DATA
   NOI RN
2.0GHZ 1.49 0.86 16.4 16.34
3.0GHZ 1.75 0.82 24.6 14.23
4.0GHZ 2.16 0.79 33.5 12.76
5.0GHZ 2.59 0.75 41.5 11.30
6.0GHZ 3.00 0.71 50.3 10.14
```

```
7.0GHZ 3.49 0.67 57.7 9.00
8.0GHZ 3.88 0.63 65.2 8.03
9.0GHZ 4.28 0.61 72.9 7.20
10.0GHZ 4.68 0.58 81.0 6.45
11.0GHZ 5.08 0.55 88.7 5.72
12.0GHZ 5.38 0.53 96.1 5.19
13.0GHZ 5.75 0.51 103.5 4.54
14.0GHZ 5.93 0.50 109.5 4.18
15.0GHZ 6.48 0.47 118.2 3.40
16.0GHZ 6.51 0.47 126.6 3.49
17.0GHZ 6.92 0.46 131.2 2.88
18.0GHZ 7.48 0.45 140.6 2.54
END
```

APPENDIX 3

```
#define EPS 1.0e-8
void atn(exloc)
int exloc;

{
   float R1;
   float R2;
   float R3;
   float YA1;
   float YA2;
   float ZA1;
   float ZA2;
   float ZB1;
   float ZB2;
   float Z1;
   float Z2;
   float x;
   float y;

     get_global_data(&fr, &zo, &funit, &runit, &gunit,
                     &lunit, &cunit, &lenunit, &tunit, &angunit);
     userdata(exloc, d, &sbeg); /* sets d[1] .. d[10], sbeg */
     R1=d[1]*runit; /*runit=scale factor from DIM block*/
     R2=d[2]*runit;
     R3=d[3]*runit;
     if (R1<EPS)
      R1=EPS;
     if (R2<EPS)
      R2=EPS;
     if (R3<EPS)
      R3=EPS;
     YA1=1.0/R3+1.0/zo;
     ZA1=1.0/YA1;
     ZB1=R2+ZA1;
     Z1=(R1*ZB1)/(R1+ZB1);
     x=(Z1-zo)/(Z1+zo); /*s11 real*/
     y=0.0; /*s11 imag*/
     tosn(sbeg,0,x,y);
     YA2=1.0/R1+1.0/zo;
     ZA2=1.0/YA2;
     ZB2=R2+ZA2;
     Z2=(R3*ZB2)/(R3+ZB2);
     x=(Z2-zo)/(Z2+zo); /*s22 real*/
     tosn(sbeg,3,x,y);
     x=(2.0/zo)/(1.0/ZA1+1.0/ZA2+R2/ZA1*ZA2));
     tosn(sbeg,1,x,y);
     tosn(sbeg,2,x,y);
}
#undef EPS
```

The Making of a Transistor

Matt Elwood
WRDC/ELRD

Acknowledgements

I would first like to thank the following, for their assistance in my understanding of the world of transistor fabrication.

Mr. Ed Davis, for the background knowledge of device processes and information on electron beam lithography.

Captain Mike Cheney, for the ion implantation explanation and diagram.

Mr. Ed Stutz and Jim Ehret, for their explanation of the molecular beam epitaxy system.

Dave Via, for the background information on masks and photolithography.

Part I: Background

Since the first transistor was fabricated from germanium in 1940, the advances in semiconductor technology have been numerous and great. For example, the idea of a central processing unit was unthought of until in 1970 when Intel came up with the idea and design for a simple calculator chip. This part of the industry has grown into a multi-million dollar business.

So far, all production chips are fabricated with silicon. The density of these devices continually rises and the speed of the chips continually rises, but the devices in research now would bypass the current devices by many times in speed and density.

Today's production technology is extremely large and slow compared to the technology being produced in labs today. For example, the silicon chip shown in Figure 1 has transistors that are 10 microns in size. The transistors produced in this lab at Wright-Patterson produce transistors with a size of .15 microns, or 150 nanometers. Here, the material used is gallium arsenide, which has overall better electrical characteristics.

Figure 1 Existing production silicon technology.

This report will present an overview of many of the processes used in the fabrication of transistors. It will cover the process in chronological order, from the untouched wafer to the finished transistor.

Many types of transistors exist. This report will center on the production of a FET, which is a very basic transistor. In a FET, current flows from the source to the drain in the form of electrons. This flow is controlled by the gate (See Figure 2, next page). The more current that is applied to the gate, the more electrons flow through the transistor. Because of this, transistors are used as switches.

The process of transistor fabrication is very complex and critical. One small particle of dust or too much development could ruin many weeks of work. To combat the problem of airborne particles, all of the transistor work is completed inside of a class 10 clean room, which means there are no more than 10 particles greater than one half micron (.00000005 centimeter) in one cubic meter of space. This would be equivalent to one pea in a football field, in larger terms. The need for cleanliness requires controlled entry by personnel, who wear suits that cover up most skin and clothing, through an air shower. This removes most

particles, and assures a clean, stable environment. The temperature and humidity are also kept within stable limits to insure coherence.

Today's technology is very complex compared to the first transistor, but in research labs, researchers are creating devices hundreds of times smaller than today's devices, resulting in faster and denser production chips in the future.

Part II: The Processes

Many processes are used to create gallium arsenide small geometry devices. For different devices and projects, different processes are utilized. In this section, some processes will be explained along with their significance to the total project.

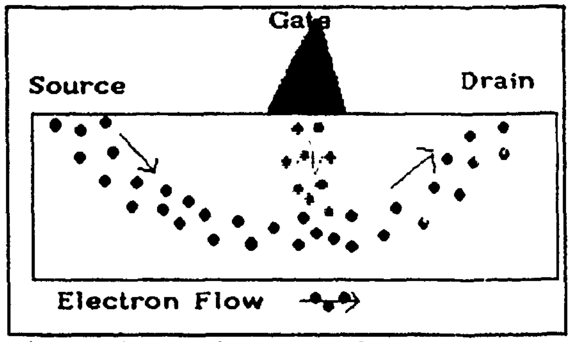


Figure 2 A side view of a FET showing current flow and control.

The entire process starts out with pure gallium arsenide wafers, called mechanical wafers. These are shipped directly from the factory where bulk gallium arsenide, called an ingot, is sliced and polished.

Gallium arsenide by itself is basically an insulator, so electrons can not flow easily around inside of the material. In order for a transistor to work, the electrons must be able to flow through the wafer (see Figure 2) easily. By doping, or adding an impurity such as silicon or aluminum to the wafer, the electron mobility is greatly enhanced.

Many methods exist for doping the pure wafer, but they can be divided into two major types, ion implantation and epitaxy. The lab here at Wright Patterson contains an ion implanter and a molecular beam epitaxy system, so this report will center on these.

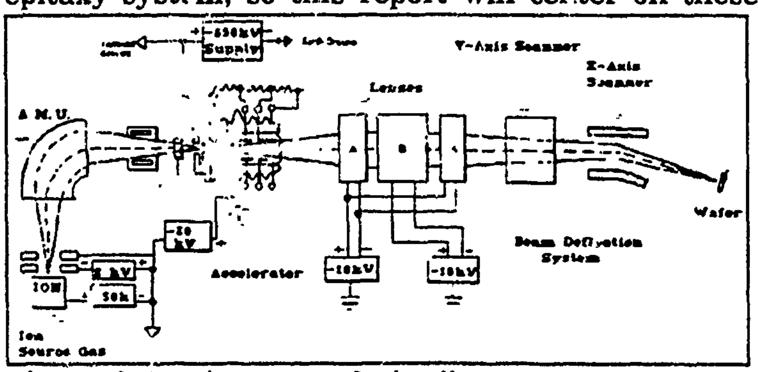


Figure 3 A schematic of the Varian-Extrion Series 400 ion implanter. (Schem. by Varian Extrion)

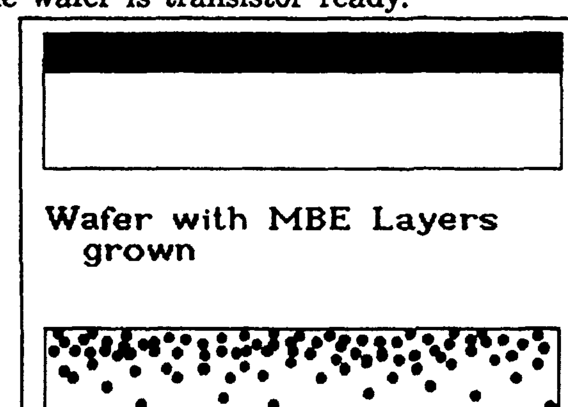
The ion implanter (Figure 3) dopes the wafer by embedding ions, which are atoms with the electrons stripped off, into the wafer. Using the implanter, many gases can be used as sources, such as silicon, aluminum, and hydrogen. Each gas has a different effect on the resulting transistors, such as enhancing the electron flow, or isolating transistors from each other electrically.

The ion implanter ionizes, or strips the electrons from the gas with a high voltage (around 1,800 volts). This is accomplished in an enclosed chamber containing a very small amount of gas and two electrodes which forms an arc when the 1,800 volts is applied. The arc strips off the electrons, and the ions, which are positively charged, are drawn into the extractor, which sends the ions into an A.M.U. Since silicon and other dopants are not made into a gas easily as an element, often compounds containing the atoms are used as the source gas, such as silicon tetraflouride. The A.M.U., which is a giant magnet, separates the pure dopant from the compounds by atomic mass. The ions are then sent into the accelerator.

The accelerator gives the ions energy, so they can sink into the wafer. By adjusting the accelerator voltage, which is normally sixty to two hundred fifty thousand volts, the controller can change the depth of the implant. After being accelerated to the high energy, the ions are steered by giant deflection magnets, so they scan across the wafer, insuring an even implant across the wafer. The deflection mechanism works much like the deflection system in a television tube does.

Ion implantation, depending on the amount of doping required, can take from 20 seconds to 30 hours to accomplish. An extra step is also required with ion implantation.

After a wafer has been implanted, the dopant or impurity atoms are randomly scattered inside of the wafer. These atoms put stress on the crystal structure. The dopants also do not effect the electrical characteristics unless part of the actual crystal structure. To relax the stresses and activate the implant, so it is effective, the wafer must be annealed. Annealing is a simple process which heats up the wafer to 800 degrees centigrade. This is usually accomplished in a furnace heated by flash lamps. After annealing, the wafer is transistor ready.

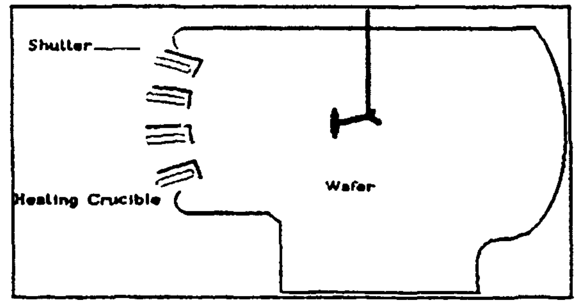


While ion implantation buries the atoms at varying depths into the wafer, molecular beam epitaxy grows new crystal layers, which may or may not be doped, on top of the mechanical wafer. This achieves different electrical characteristics. Figure 4 shows a visual comparison of the two processes.

The molecular beam epitaxy system (Figure 5) consists of eight crucibles, which hold the molten elements, and a large central chamber, which holds the wafer.

The eight crucibles contain metallic elements that are heated up to their boiling point by tantalum ovens. These crucibles may contain gallium, arsenic, aluminum, indium, silicon, or any other metal. On the front end of the crucibles are shutters, which protect the wafer from any accidental spray of the metal from the crucibles. Pumps control the

spray of elements onto the wafer. The wafer is kept in a large vacuum chamber at 600 degrees centigrade, around 12 cm from the shutters.



To grow a layer, the operator opens the shutters in front of the desired elements. He then turns the pumps on in front of the elements, and a small layer is evaporated or grown on top of the wafer.

Annealing is not required after molecular beam epitaxy. Since the elements are already at a very high temperature, they naturally form stable crystals without reheating.

Two major doping methods exist, epitaxy and ion implantation. While ion implantation buries atoms of a dopant at varying depths, molecular beam epitaxy grows new layers of doped gallium arsenide on top of the wafer. Ion implantation requires annealing to activate the implant and relieve the strain on the crystal structure of implantation, while molecular beam epitaxy does not, because crystal layers are formed already.

Once the wafer has been prepared, either by epitaxy or ion implantation, the researcher may write gates on to the wafer by a process called lithography. This is the most crucial and complex part of the process.

Two types of proven lithography exist, photolithography and electron beam lithography. Researchers are developing X-ray lithography, but that process is still unstable.

Photolithography was the first process used. It involves exposing patterns (called masks) onto wafers with deep ultraviolet light. This process has been used in production in many years. Photolithography is reaching the resolution limits, though. The minimum size gate that photolithography can write is around 1 micron. Processes of this size are already being utilized in commercial products, so photolithography's purpose is not to make smaller, more densely packed gates, but rather to manufacture, optimize, and test new devices and processes on a larger scale.

All new wafer designs begin on the computer screen of a special CAD workstation. The designer there lays out the arrangement of gates with special computer aided design software. Many different techniques can be used to transfer the design from a computer display to micron-sized designs on masks.

The least efficient technique in terms of size is rubylith. Rubylith is a ultra-violet blocking coating on a large piece of acetate. The design is scribed on the rubylith with a large knife plotter. Part of the rubylith is then removed by hand to create a pattern of rubylith and clear areas. The rubylith is then placed in front of a ultraviolet source and reduced with lenses onto a mask at the desired geometry. Unfortunately, rubylith has a resolution limit of 50 microns.

Rubylith is a type of photoreduction. Photoreduction can also be used with any high-contrast master pattern and step-down lenses. The pattern is always reproduced on a coated glass mask.

The process used here utilizes the electron-beam lithography system. The E-beam system converts the data directly from the CAD format to a raster format understood by the machine. Then it creates a pattern that, when developed, can produce one-half micron gates.

Once a designer has finished a mask, many individual wafers can be made from the same design. The wafers must be prepared before exposure, though.

After a wafer has been implanted or had layers grown with MBE, photoresist must be coated on the wafer. Photoresist is an organic chemical that is sensitive to ultraviolet light, electron beams, or X-rays depending on the process. Many layers of different photoresists may be used, or just one, depending on the desired result. Photoresists can also be light-phase or dark-phase, which can equate to negatives or positives in photography.

Once the wafer has been coated with photoresist, the mask is placed above a wafer inside an exposure tower. The exposure tower contains an ultraviolet light and a focusing system, much like a photographic enlarger. The ultraviolet light exposes the photoresist.

The pattern is then developed by chemicals, which dissolve the unexposed or exposed photoresist away. Then an optical microscope may be used to examine the remaining resist.

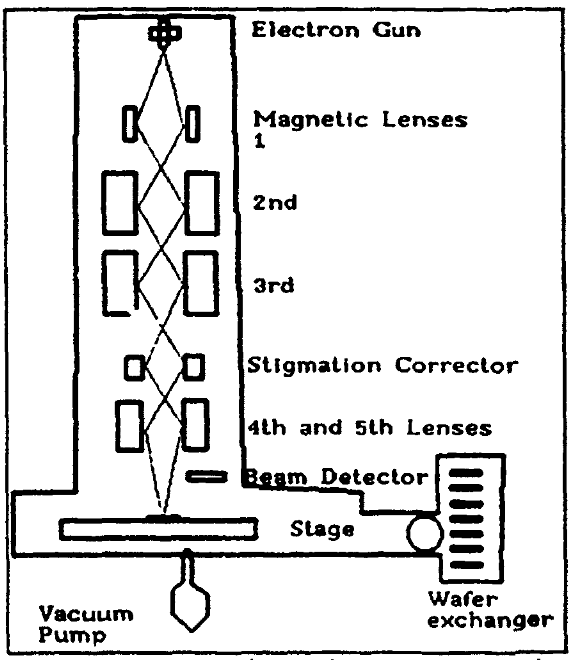


Figure 4 A simplified diagram of the JEOL JBX-5DII electron beam lithography system.

The other type of lithography used here is electron beam lithography. Since electrons are much smaller than the wavelength of light, researchers have fabricated gates as small as .07 micron (70 nm). Theoretically, gates much smaller than the .07 micron could be produced, but because of electron scattering in the photoresist, that is impossible with current resist technology.

The wafer is first coated with layers of photoresist, but a different type that is sensitive only to electrons. The wafer is then loaded into the lithography system (Fig 6). After focusing the beam and adjusting the beam's astigmatism for the tightest and roundest beam, the beam writes a pattern at a predetermined dose on the wafer. Depending on the complexity of the pattern, a write may take from one hour to four or five hours.

The electron beam lithography system employs high voltages (twenty-five or fifty kilovolts) to create the beam. The beam is actually produced from a lanthanum hexaboride tip at the top of a column. Inside of the column, magnet "lenses" control the focus, astigmatism, and beam size. The wafer is held at the bottom. The entire system is inside a very high vacuum and mounted on a vibration-proof pad.

Since electron beam lithography creates gates smaller than the wavelength of light, detailed pictures can not be resolved with a normal light microscope. A scanning electron beam microscope is then employed to examine the resist profiles or gates.

The scanning electron microscope works much like the electron beam lithography system. A filament produces a beam of electrons at the top of a column and magnet "lenses" control the beam parameters. Added to the scanning electron microscope is the detector. This turns the amount of electrons reflected by the surface into a lightness or darkness value, which is displayed on the monitor. The maximum resolution of a scanning electron microscope is 300,000X.

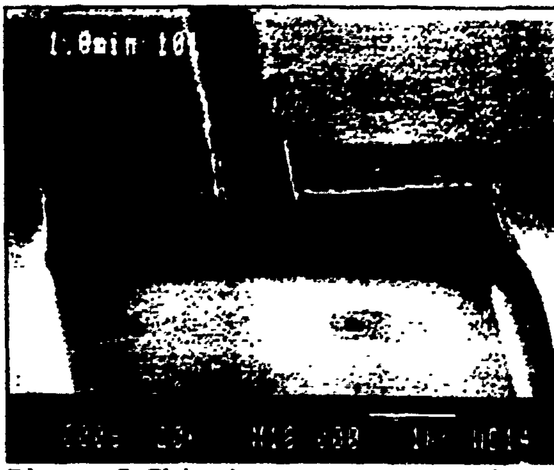


Figure 7 This is a resist profile SEM micrograph. Three layers of resist and one layer of gold were coated onto the wafer.

Unfortunately, the SEM has its disadvantages. The SEM also utilizes an electron beam, so it destroys the resist as an engineer looks at it. The SEM also can not view organic materials, for they charge up and don't reflect any electrons, or reflect all of them at once, showing up as dark or light spots on the video display. A solution to this is sputtering, in which a very thin layer of gold is evaporated onto the sample. A picture of a resist profile from a SEM is shown in Figure 7, and a high magnification picture is shown in Figure 8.

If a sample looks good, it may be carried through the end of the process. In the end of the process, the wafer is metallized with gold. The gold is extremely thin, about 3000 angstroms thick, which equates to three hundred nanometers. The gold fills in part of the impressions in the resist and covers the resist.

After the wafer has been metallized, the resist may be lifted off. To achieve this, the wafer is placed in a solvent at around 250 degrees centigrade. When the resist is lifted, the gold on top of the resist is also lifted, leaving only gold gates above the gallium arsenide wafer surface.

This is the end of the process. After the resist has been lifted, the remaining gold gates are the transistors. After the process, the transistors may be tested. For test projects, large gold pads are usually included for the source and drain for the testing probes to touch. The testing probe places fine wires on the gold pads and the gate to test the

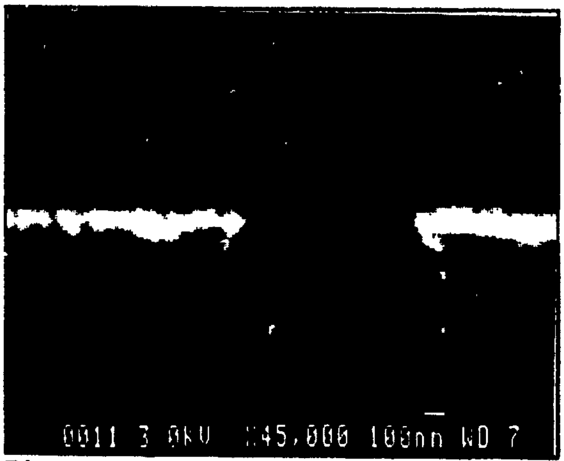


Figure 8 A photoresist SEM micrograph looking from the side.

transistor's parameters.

After microscope inspection of a wafer reveals suitable resist patterns, the wafer may be metallized. After metallization, the extra resist and gold is lifted, leaving only the gold gates. The transistors may be tested then by a probe.

This is a simplified version of the process of transistor fabrication. Many variations may be needed for different devices and experiments. For example, multi layer chips require these steps, plus more, for each layer of the chip.

I have participated in research involving many of these steps. I have run the ion implanter for other people's projects. I have also developed wafers and used the SEM to examine wafers that the electron beam lithography system wrote. Although I did not directly participate in all of these processes, other engineers and technicians have explained them to me in great detail. Through the combination of these I have learned much about transistor fabrication in the eight weeks I have spent here.

IMAGEPRO USER GUIDE

by Shelly Knupp

Mentor: Kirk Weigand

Wright Research and Development Center

Electro-Optics Techniques & Applications Branch

June - August 1990

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I would like to express my gratitude to the people that have assisted me in my eight week stay here at Wright-Patterson Air Force Base - my mentor, Kirk Weigand, and other engineers who helped me within the laboratory; Dale Stevens, Jeff Brown, and John Hoeft. I would also like to thank Dick Lane for his direction and Nicole Wall for helping me prepare my final report. Thanks to everyone in ELOT for making me feel welcome at Wright-Patterson.

Introduction

As a UES high school summer apprentice working under Kirk Weigand in the Wright Research and Development Center, Electro-Optics Techniques & Applications Branch, I've learned a lot about the non-laboratory work that engineers may do. The project I was working on for my mentor, exploring existing machine vision/target recognition technology to find a way to automate a system to sort commingled recyclables has resulted mostly in library and computer work. I worked to design and build a database to file articles that I found in a comprehensive library search. I also spent a lot of my time in exploring the Imagepro image processing system in our laboratory. Near the end of my summer, I also aided Jeff Brown, a physicist in our division, in the computer plotting of data from an experiment on GaAs wafers. The culmination of my summer work can be seen in this report. I was asked to write a mini-manual to make our image processing system more accessible to new users. This user guide and information about the application of this specific computer system to our research is included.

IMAGEPRO USER FRIENDLY GUIDE

Whether it is a blessing or unfortunate, you have the task of learning how to use Imagepro ahead of you. You have at your access the Imagepro manual that is supplied by Imagepro, but if you are not familiar with any image processing programs, this guide can be more confusing than helpful. And for that reason, this guide was created to put learning the Imagepro basics within your reach. Good Luck!

GETTING STARTED

Turn on the computer. Make sure both monitors and the camera driver system are on. Make sure that you can see an image of the object in front of the camera on one of the monitor screens.

Your first task is to get into Imagepro. When you turn on the computer it would seem that it should be simple enough to type in the command from the DOS screen, but if you go directly from the computer starting menu to Imagepro through the **IMAG** command, you will get into Imagepro, but not be able to bring any new images in with you. This is because Imagepro's **capture** function does not work. If you enter Imagepro through the **IMAG** command, your only option will be to perform functions on images that already exist within the Imagepro directory. To enter Imagepro and be able to perform functions on the image of the object that is currently in front of your camera, follow this next routine of commands.

Type **cd ecp** - This changes the directory to a program called ecp that has the capabilities to capture images.

Type **auto**

Type **frame cc** - This gives you continuous capture of the image in front of your camera and will allow you to get it in position for the next step.

Type **frame co** - This turns the continuous capture off so that the the camera captures one frame.

Type **cd..** - This exits the ecp directory.

Type **cd imagepro**

Type **imagepro/n**

These steps will bring you and your image to Imagepro's main menu, otherwise known as the home menu. If you do not care to bring an image in, simply type **imag** at the first prompt after you turn the computer on.

NOTE

This manual mainly concerns orientating the new user to functions that are most helpful in acquainting him/her with the capabilities of Imagepro. Because many of the other more technical functions are not dealt with, as soon as the user gets more proficient, he/she should first turn to the complete function outline at the back of this manual for an brief overview of other Imagepro functions, and then go to Imagepro's provided manual.

Below is a replica of Imagepro's main menu.

Current Filename is DEFAULT.PIC

View Current Image	Palette Editor
New Image	Utilities
Image Analysis	HALOVision Editor
Image Measurement	Clear Image
Image Operations	Capture Image
Global Attributes	User Modules
Execute Script File	Write Image

If you would like to perform functions on the image you captured in the ecp initialization process, you must save that image. Notice that on the top of the main menu the statement says "Current Filename is ________", and it names an image you are probably not familiar with. If you would go to select any of the functions, the computer would perform these functions on the current filename image regardless of the fact that you have captured an image in ecp. Your recently captured file has not been entered into imagepro and it is only temporarily in ecp. To store your file, use the mouse or the arrow keys to select **WRITE IMAGE**. The program now asks you to "Enter Image File name". Type in the name of your file, eight letters or less, hit return, and Imagepro

will save it in it's directory with the suffix **.pic** attached to signify it is a picture.

If you are not interested in saving the image you captured in ecp, your option is to work with images already in the imagepro directory. To do this, select the main menu function **New Image** and when prompted "Enter Filename" it would be better to follow the directions on the bottom of the screen and call up the Imagepro file directory. Once in this directory, select an image and when the screen returns to the main menu, you will notice that the image you selected is identified in the "Current filename is" blank. When you turn to your monitor to view this new Imagepro image, you will notice that the image on the screen has not changed. To look at the image you retrieved from the Imagepro file, you must use the **View Current Image** function. Select this and the new image will appear. With the new image on the screen you are now ready to start working with some of the other, more exciting Imagepro functions.

First, we will look at the **Image Analysis** functions. Select **Image Analysis** from the main menu and the computer will bring you to your first sub-menu. Most of the functions on this menu are used to analytically take data on parts of an image. For the beginning Imagepro user these functions are of little importance in his/her goal to get acquainted with Imagepro. If the user wishes to learn about **Histograms**, **Reports**, ect. he/she should first check out the Main Function Outline at the back of this manual, and then turn to the Imagepro Manual. We will work with the **Magnify Image** function.

After selecting **Magnify Image**, your screen will display these charts.

Magnification
1.00

Coordinates	Index	Red	Green	Blue
(0, 0)	0	0	0	0
(511, 511)	0	0	0	0

The magnification box tells us how many times the image on the screen is magnified. The chart below this gives more technical information on specific points, their indexes and their red, green and blue measures. Directions to magnify are locates at the bottom of the screen, but they will be repeated here. Hold the right button on the mouse down while moving it up and down to increase and decrease magnification. Notice how the values in the magnification indicator box change with how large or small you have made the image. As the screen instructs, click the left button to quit. Now that you have some experience with an **Image Analysis** function, select **prev menu** and return to the home menu.

The next group of functions we will look at are the **Image Measurement** functions. After selecting this from the main menu, you will again be referred to a sub-menu. From this, select **Measure Distance**. The screen now displays that "Line Distance = 15.55635 units" and a chart with coordinates, indexes, and red/green/blue values. (It is very similar to the chart that you saw before.) The image monitor screen displays the image with a short slant line on it. Use the mouse to move the line around on the image. By holding the right button down on the mouse, you anchor the line, and by moving the mouse around with the right button held down, you achieve lines of different angles and lengths. Notice that as you do this, the values measuring the line's distance change and these changes are displayed on the computer monitor. When you are finished with this, click the left mouse button to return to the sub menu. Next, select **Trace and Measure Area**. The image monitor displays a + on the image. As you move this indicator around, the chart on the computer monitor displays the specific coordinates of the point that the indicator is on. By holding the right mouse button down, trace around some specific area on your image. Make sure the end and beginning of your line are connected. Then move the + indicator into the inside of the area, and

click with the left button. The screen will blacken this area of the image to signify exactly what area has been measured. Your charts on the monitor will display the length and area measurement figures. Try to repeat the similar process with the **Trace and Measure Line** function and observe the results. Hit **prev menu** to return to the home menu.

The next set of functions we will look at are the **Image Operations** functions. Select this to view the first sub-menu which is reproduced below.

Image Operations

Build Composite Image	Posterize Image
Color Index Replacement	Replicate Image
Color Index Shifting	Rotate Image
Contour Image	Scale Image
Contrast Enhancement	Spatial Filtering
Histogram Equalization	Threshold Image
Multi-Image Operations	Unary Operations

The **Image Operations** functions, depending on your application, are probably the most useful group of Imagepro functions. Select the first, **Build Composite Image.** The computer now asks "filename to add". Hit the mouse's right button to call up the directory and then make a selection from this. The object of this function is to overlay a selected .pic file over the a part of the image you have been working with. Next you are asked to select an area of interest from the numbered area chart. We will go into greater detail about this later, but for now move the selector to **Locator** with the mouse, and select this. On the image monitor screen, a small box will appear. Move the box around by using the mouse. Next, hold the mouse right button down to anchor the box, move the mouse in all directions to stretch, compress, and change the size of this "rubberband box". Let off the right button when you have found the box you want and click on the left button. Now you have initialized **Build Composite Image.** Watch the image monitor. First it will reproduce the "filename to add" that you chose, and then it will reduce the size of the picture to the size of the final rubberband box you made. Finally, it will bring

your original working image with it's composite up.

Return to the first **Image Operations** sub-menu. Notice that there are two functions dealing with color indexes, and others dealing with contour, contrast, and histogram equalization. These are very useful when processing more complicated applications, but to acquaint the user with Imagepro, we will only examine one of these. Please select **Color Index Shifting.**

The computer will bring you, as before, to the screen for selecting an area of interest. Use the **Locator** and rubberband box to select a desired area of interest, just as we did in building a composite image. The computer monitor screen will display a chart with range, index, and red/green/blue measurements. The image monitor will display a color bar (actually a bar of different shades of gray since this is a black and white image) in the top left corner. The color bar will also have a small line on it that can be moved by using the mouse. The computer prompts you to "select indexes to shift". You can do this by moving the line on the color bar with the mouse and clicking it on the desired index. Now the computer monitor displays a start/end chart and a new color bar. By moving the line on the image monitor across the bar, notice that the values in the chart on the computer monitor also change. By clicking the left button you select the color the shift the indexes to. Imagepro processes this, and the results are shown, but since the image is in a black and white mode the results are very vague.

Return to the first **Image Operations** sub-menu and select **Multi-Image Operations.** Select an area of interest by using the **locator** and rubberband box as we did before. The computer monitor screen will display another sub screen listing the Boolean operations. The purpose of a Boolean operation is to combine the pixel specifications in whatever way the user selects. For example, if **subtract** was selected, Imagepro would subtract the pixel values of one image from

the pixel values of another. In this case, select **and.** The computer prompts you to "retrieve image from disk file or display page". Select disk file and use the directory to call up a filename that you would like to perform the **and** with. The computer will **and** the chosen file and your original image. Results may be difficult to tell.

Return to the first **Image Operations** sub-menu and select **Replicate Image.** (You may wish to go back to Imagepro's main menu and use the **View Current Image** function to erase any of the functions you have performed on the image.) Once in **Replicate Image,** the computer asks you how many times you want to replicate it...**2,4,8,** or **16.** Select 8 and observe that 8 smaller versions of your image appear on the image screen. Return to the main menu to erase this change through the **View Current Image** function. This allows you to perform operations on the original image.

Come back into the **Image Operations** and select **Rotate Image.** Select an area of interest. The computer monitor now displays an angle chart and the image screen displays an angle line that can be rotated by moving the mouse. As you move the mouse, watch the angle values on the screen increase and decrease. Click the left mouse button when you have moved to an angle near 180 degrees and the computer rotates the area of interest that you selected 180 degrees on the image screen.

Return to the first sub-menu and select **Spatial Filtering.** Select an area of interest. Select **Laplacian** filter from the filter sub menu. Observe on the image monitor screen how the computer filters the image. This process can be repeated for all the filters and also for the sub menu of **Non-Convolution** filters. Filters are more helpful for the user who is dealing with more complicated applications, but the new user should be aware of the possibilities.

Return to the main menu and select **Global Attributes.** As you saw before, many functions require you to use an area

of interest. Through this next function, you will not have to use the rubberband box process every time that you need an area of interest. Select **Define Area of Interest** from the **Global Attributes** sub-menu. The computer screen displays a chart of 8 areas of interest to define. Once defined, the user will just click on the area number to call up an area of interest. Go through the rubberband box process to define the 8 area of interest. The other 5 areas are predefined through Imagepro. These include the 4 quadrants of the screen and the whole screen. Return to Imagepro's main menu.

Select **Palette Editor**. When the computer presents the first sub menu, choose **Set New Palette**. This will bring up the next sub menu that is shown below.

Palette Editor

Linear, True Color
Exponential, True Color
Default Color
Linear, Black and White
Exponential, Black and White
User-specified Palette

By choosing any of the first four functions on this sub menu, the user plugs in a specified formula and the computer changes the color in the image. Note: It is important to understand that the any color the computer assigns to images is representative color. The computer camera captures the image in black and white, and the image cannot be presented in the colors we see with our eyes, because it is a black and white camera. By choosing **User Specified Palette**, you can transfer a palette of colors from an already stored image to your own image. Select this. When prompted for a filename, call up the directory and select a file from it. Observe the image screen changing. Exit **Palette Editor** to the main menu.

The next option on the main menu to select is **Utilities**. Within this option are useful functions which allow you to delete entire image files, print images if your computer is hooked up to a printer, change filenames and more. The goal

of this next routine is to complete a function where we can "**cut**" an area of interest from one image file and move it to another image file. To do this select **Set file type** and choose **cut**. Next, select **write cut file** and select an area of interest as we have done in previous cases. When asked for a filename for the cut file, type in a name that identifies the area of interest and the file. When asked if the machine should reduce color indices, answer **no**. Next, return to the main menu and pull up a new file. Use both **New Image** and **View Current Image** functions to bring the image onto the screen. Return to the **Utilities** menu and select **Read Cut File**. When asked which file to read, use the directory and selector to choose the file you just created. Next, a box will appear on the image screen that is the same size as the cut file which you created. By use of the mouse, move this box where you want the cut file to be placed and click the left button.

After returning to the main menu, select **Clear Image**. You will be asked to respond to the question "OK to clear image?" Answering **yes** will clear the image from the screen. Two other basic Imagepro functions are the **Capture Image** and **Write Image** functions. **Capture Image** is inoperative at this time and that was the reason for capturing through ecp in the start of this routine. As we learned in the beginning, **Write Image** is for saving an image in Imagepro once it has been captured.

Whew! Now you have finished a basic routine that should have helped acquaint you with Imagepro. You can find out more in the last section of this manual. This "Imagepro Main Menu Function" outline states each of the steps under the main menu functions. It covers all of the menus and sub-menus thoroughly. Of course, you can also turn to the Imagepro Manual for a more in depth study of Imagepro's capabilities.

IMAGEPRO FAILURES

This section is included to orientate the user to what has been done, up to date, to solve the operating problems in Imagepro.

The Capture Function Problem

As explained in this "User-Friendly Guide", to bring an image into Imagepro, the user must complete the ecp capture routine because the Imagepro capture function is inoperative. After making several contacts with the 3M Imagepro representatives, and after having been sent diagnostics and test routines for ecp, we were still unsuccessful in solving this problem. In general the 3M/Comtal representatives were ineffective in troubleshooting this problem over the phone. Ben Woolridge of 3M/Comtal has suggested that we send them the computer, cards and camera, and they will do a full diagnostic test for $250.00. Depending on your use of **Capture Image**, this issue can either be of no concern or can be a serious problem. The lack of a printer driver for one of our printers is another problem.

IMAGEPRO APPLICATIONS

This section discusses our attempt to apply Imagepro to the sorting of recyclables.

Because of the increase in numbers of concerned people who are facing the reality of the environmental problem that is in our hands, we realize that the implementation of recycling programs is becoming more and more imminent to the survival of the planet.

Current recycling programs are both ineffective and tedious in handling the volume of trash that needs to be recycled. This is because they are carried out by people who hand sort trash. Our goal was directed to using machine vision and target recognition to recognize commingled recyclables as they move down a conveyer line and sort these into recycling bins. Such an automated machine vision sorting system would be much less manpower intensive and therefore, much less expensive in the long run.

Machine Vision/Target Recognition is currently under research by the military for it's military applications, but it is also a new technology that can have many domestic applications. An actual military to domestic technology transfer is becoming very important if the U.S. is to survive in the world market, and environmentally, if we are to survive at all.

Our first plan for solving this problem included researching to find what types of machine vision systems already existed. We began with a literature search of existing databases and found many articles to fill our own files. Many articles discussed research, while others gave information on the current machine vision systems which have been sucessfully applied by engineers to small sorting problems. These sucessful applications include the sorting of anything from boll worm larvae to homogeneous glass bottles to a local commercial user of an Allen Bradley machine vision system who was sorting cookies.

We recognized that for our problem of sorting commingled recyclable, there would be endless compositions of positions, shapes, and patterns that a computer would have to recognize just in the sorting of soft drink cans. We attempted to explore Imagepro's possibilities in eventually sorting recyclable by entering several different kinds of soft drink can images into the computer and working with different functions to see if there was any combination of functions that would lead to applicable computer vision recognition. Because of Imagepro's capture function failures, we could only go so far with exploring this. We believe that not only Imagepro, but all the other existing technology is insufficient to efficiently solve our machine vision recycling problem, and that optical preprocessing technologies must be updated to tackle this problem. We think that it is only a matter of time before machine vision systems can be created to handle complicated target recognition tasks such as sorting commingled recyclables.

Imagepro Main Menu Functions

I. View Current Image

II. New Image

III. Image Analysis
- A. Histogram of a Point
- B. Histogram of a Line
  - 1. Gives the mean, mode, median, and standard review.
  - 2. Display accumulated histogram?
  - 3. Display pixel counts by index?
  - 4. Calculate points within index range?
- C. Histogram of an Area of Interest
  - (steps 1. - 4. from B.)
- D. Magnify Image
- E. Profile of a Line
  - 1. Display profile data.
- F. Report Generator
  - 1. Identify Area of Interest (AOI) chart.
  - 2. Name of Graph file with directory option.
    - a. Gives an graph generated from another file.
- G. Frequency Analysis
  - 1. Display frequency counts.
- H. Global Attributes
  - (see VI.)

IV. Image Measurement
- A. Measure Distance
  - 1. Displays chart with line distances.
- B. Measure Radial Distance
- C. Set Calibration
  - 1. Set calibration.
  - 2. Set unit name.
- D. Trace and Measure
  - 1. Display point coordinates.
  - 2. Read point coordinates in directory.
    - (no directory exists- beeping)
  - 3. Save point coordinates within directory.
    - (see 2.)
  - 4. Trace and measure area.
  - 5. Trace and measure line.

V. Image Operations
- A. Build Composite Image
  - 1. File name to add.
  - 2. Select Area of Interest.
- B. Color Index Replacement
  - 1. Select Area of Interest.
  - 2. Select Index or Indexes to replace.
    - a. color bar
  - 3. Replacement Value.
- C. Color Index Shifting

1. Select Area of Interest
2. Select Index to shift.
    a. color bar
3. Start/End (shows dots on screen)

D. Contour Image
1. Select foreground color.
    a. color bar
2. Transparent background?
3. Range/Index (stretch range)
    a. color bar
4. Map palette to image?

E. Contrast Enhancement
1. Select Area of Interest.
2. Select enhancement range.
3. Slope/y-intercept.

F. Histogram Equilization
1. Select Area of Interest.
2. Equilization Curve.
    a. Bell
    b. Cube
    c. Exponential
    d. Linear
    e. Log
3. Map palette to image?

G. Multi-Image Operations
1. Select Area of Interest.
2. Subtract
    a. Retrieve Image from
        i. disk file- enter file name.
        ii. display page- pg.2,3, or 4.
3. Add (see 2a.i.-ii.)
4. Average (see 2a.i..-ii.)
5. And (see 2a.i.-ii.)
6. Or (see 2a.i-ii.)
7. Nor (see 2ai.-ii.)
8. Nand (see 2ai.-ii.)
9. Difference
10. Matte
11. Multiply
12. Divide
13. Scale/Boost

H. Posterize Image
1. Select Area of Interest.
2. How many colors?__
3. Reduce resolution by 1,2,4,8,16,32,64,128.

I. Replicate Image
1. 2,4,6,or 16 images?

J. Rotate Image
1. Select Area of Interest.
2. Angle? __

K. Scale Image
1. Select Area of Interest.

L. Spatial Filters
1. Select Area of Interest.

```
    2. Convolution Filters.
         a. Lo pass filter.
         b. High pass filter.
         c. Laplacian filter.
         d. Horizontal edge.
         e. Vertical edge.
         f. User specified.
              i. enter mask name.
         g. Mask Maintainence.
              i. get mask from disk.
                   aa. enter mask name.
              ii. edit current mask (on chart).
              iii. new mask creation.
                   aa. (gives 3x3, 9 space graph).
              iv. save mask to disk.
                   aa. enter mask name.
         h. Scale and Boost.
              i. set filter scale.
                   aa. enter filter scale.
              ii. set filter boost.
                   aa. enter filter boost.
              iii. reset to default.
         i. Set filter size.
              i. 3x3
              ii. 5x5
              iii. 7x7
    3. Non-Convolution
         a. dialation filter.
         b. erosion filter.
         c. medial filter.
         d. sobel filter.
         e. unsharp mask.
         f. scale and boost (see 2.h.i.-iii.)
         g. set filter size (see 2.i.i.-iii.)
         h. convolution (see 2.a.-i.)
M. Threshold Image
    1. Select forground color.
         a. color bar.
    2. Transparent background?
         a. no- select background color.
              i. move across color bar to select
                 threshold level.
N. Unary Operations
    1. Select Area of Interest.
    2. Or.
         a. input mask value (bianary) ________.
         b. input right rotate count _.
    3. And (see 2.a.-b.)
    4. Xor (see 2.a.-b.)
    5. Nand (see 2.a.-b.)
    6. Nor (see 2.a.-b.)
    7. Add (see 2.a.-b.)
    8. Sub (see 2.a.-b.)
    9. Mul (see 2.a.-b.)
```

10. Div (see 2.a.-b.)

VI. Global Attributes
A. Calibrate Measurement
1. Set Calibration.
a. Select area.
2. Set unit name
a. Enter unit name.
B. Define Area of Interest.
1. (given 8 areas to define).
C. Define Color Model
1. RGB Model
2. HLS Model
3. HSV Model
D. Define Scale and Boost
1. (see V.L.h.)
E. Read Global Attributes
F. Set Black and White
1. Turn on.
2. Turn off.
G. Set Display Page
1.,2.,3., or 4.
H. Set Locator Delay
1. Enter Delay.
I. Set Histogram Location
1. Current location is quadrant __.
J. Set Report Attributes
1. Set font type.
a. centital
b. centmed
c. cursbold
d. cursive
e. gothic
f. greek
g. halo 201
h. halo 202
i. halo 203
j. halo 204
k. halo 205
l. halo 206
m. halo 207
n. halo 208
o. italic
p. Roman 1
q. Roman 2
r. Roman 3
2. Set foreground color.
a. color bar.
3. Set background color
K. Set Snapshot Filename
1. Enter name of snapshot file (from directory).
L. Write Global Attributes

VII. Execute Script File
A. Enter Filename (from directory)

VIII. Palette Editor
A. Display Palette (graph)
B. Edit Color Index
1. Select or Stretch Color range.
a. color bar.
2. Move line up or down along y-intercept in mini x/y graph on screen.

C. Edit Screen Index
    1. use + on screen to select pt.
D. Remap to Linear
E. Save Current Function
    1. Enter Palette name.
F. Set New Palette
    1. Linear true color.
    2. Exponential true color.
    3. Default color.
    4. Linear, black and white.
    5. User Specified Palette.
        a. enter palette name (from directory).
G. Global Attributes
    1. (see V).

IX. Utilities
- A. Copy File
    1. Enter filename of source.
    2. Enter filename of destination.
- B. Copy Page
    1. Copy to display page.
        a. 2-4
- C. Delete File
    1. Enter filename to delete.
- D. Disk Directory
    1. Directory of drive.
- E. Free Space
    1. Free space on drive?__
- F. Print Image
    1. Print current screen.
- G. Read Cut File
    1. Enter filename.
- H. Rename File
    1. Enter filename of source.
    2. Enter filename of destination.
- I. Set File Type
    1. Cut   5. Palette
    2. Data   6. Point
    3. Image   7. Script
    4. Mask
- J. Write Cut File
    1. Select Area of Interest.
    2. Enter file name.
    3. Reduce color indices.

X. Halovision Editor
- A. Please Stand By, Loading Image Editor.
- B. Halovision screen.

XI. Clear Image
- A. OK to Clear Image? Y/N

XII. Capture Image
- A. Single Frame
- B. Continuous Capture

XIII. User Modules
    A. None Existing now

XIV. Write Image
    A. Enter Image Filename

Final Report

AFSOR High School Apprenticeship Program

Christopher O'Dell

Mentor: Luis Concha

Electronics Technology Laboratory

Computer-Aided Design (CAD) Area

WRDC/ELED

Friday, August 10, 1990

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II. General Description of Research

Over the summer I worked on two basic projects, the first being the design of a DCL (Digital Command Language) program that automated a series of tests, and the second an exploratory development project involving the design and simulation of circuits on a computer-aided design (CAD) system.

A. My first project was conducting a series of about 325 benchmark tests . Benchmark tests are tests, run from a computer terminal, that evaluate commercial VHDL (VHSIC Hardware Description Language) toolset packages. VHDL is a computer language that describes VHSIC, or Very-High Speed Integrated Circuits, circuitry. I was tasked with testing Intermetrics Corporation's toolset package. Running the tests turned out to be very manpower intensive because each benchmark test had to be run separately. I informed my superiors of this, and it was suggested that I write programs to make the testing process less time consuming. After much frustration and several variations, I finally was able to create a series of programs that, in effect, automated the benchmark tests to a workable level. The programs allowed for input from the testor on the tests to be run and the needed information to run that specific test. The programs made it possible to run many tests together, greatly speeding up the process. The programs ran the tests without any other outside help, and would then organize the data neatly for the testor.

The automation program has the potential to have a significant impact upon the laboratory. It provides the opportunity for any user to run the tests with virtually no computer or VHDL knowledge, it speeds up the testing process, and is user-friendly. The program was approved by my mentor's superior, the chief of the Design Branch in the Electronics Technology Laboratory, and then incorporated into the benchmark program in the laboratory.

B. The second project I worked on was drawing and simulating circuits using a commercial software package. I was given circuitry designs on paper, and then I redrew them on a computer, made the necessary changes, and simulated them to see if they indeed worked. If they did not function correctly or did not have adequate performance I would work with an engineer on modifications until the circuit reached an acceptable performance level.

The circuits that I drew and simulated, to make sure that they worked at a high performance level, will eventually be retested by engineers and converted into hardware (if it is judged that they are useful). My work was important because the type of circuits I tested generally work only about ten percent of the time. It's critical that the government know that the circuits function properly before they are constructed.

Both of the projects that I worked on this summer were associated with the ongoing VHDL project of designing and testing circuitry. To sum up, the first project I did automated benchmark tests, and the second was actually VHDL design and simulation work. The VHDL program in the Electronics Technology laboratory is just one of many projects occurring there. The benchmark tests that I automated test the commercial VHDL toolsets, so that the government will be able to judge which one to buy for the laboratory. The toolsets control the VHDL language and help design and simulate the VHSIC integrated circuits to make sure that they work, and more importantly, that they work well. The two projects I explored are prime examples of the VHDL work that occurs in the computer-aided design area of the Electronics Technology laboratory.

III. Detailed Description of Projects

A. In tackling my first assignment, writing a DCL program to automate the VHDL benchmark tests, I had several smaller tasks to complete. The apparatus I worked on to run the benchmark tests and write the automation program was the VAX/VMS systems 8800, a "user-friendly" network of computers . I had to learn the entire DCL computer programming language from scratch, having had little previous experience in computer programming besides learning the BASIC programming language. I spent several afternoons just reading and experimenting with the language, for I had to know DCL inside and out in order to complete my task. Then I experimented with several benchmark tests to observe how they ran and to discover the general format and commands involved with running them, to see what I was up against, and to determine the best strategy to use. Five commands are required to run each test. Each test had differing names and parameters. After experimenting, I began to write the program.

My next task was the creation of a method to facilitate user (benchmark testor) input of the needed information, the information that differed between each test. The test-unique data were test number, pathname (where the test file was located), name of test file, number of variations (versions) of each test, and parameters of each version. First, I created a small command file (note: the words "program" and "command

file" are used interchangeably in DCL) that would tie together the five commands to run one test, and then run the benchmark test by itself. It was a very simple p. jram compared to what would evolve later, yet it was a good start. However, to run a specific test, the user had to manually edit the command file to change the differing information (test number, pathname, filename, version, and parameters). I judged that it would be more efficient if I could run several tests with one command, so I could start the tests and then leave and do something else. This was the real challenge, and it took me several weeks to accomplish this very difficult task. I greatly changed the simple command file that I had started with, and created an additional command file. These two programs worked together, and greatly facilitated the benchmark testing process. All that was required of the user was that he/she enter into the computer the differing data between the tests he/she wanted to run; and the computer would then take over. It copied the necessary files, created several temporary programs, edited several others, ran all the necessary command files, and wrote the output to a file to be examined by the user. But I did not stop there; I felt that the program still lacked something. I added two features to my program, which in my eyes greatly increased its value. First, I modified one of the command files so that when the user inputs the necessary data into the computer once for a specific test, and then decides to run the same test again, the previously entered information will have been saved and can be recalled by the

program. When the user tells the computer which test he/she wants to run, the computer will check to see if it already has the needed information, and will recall it. The second change that I added dealt with the output files. There are almost four pages worth of output from each test that is run. The only useful information in these four pages of text is about ten lines dealing with the CPU (central processing unit) times. I created an additional program which, at the end of each test run, scans the output file, reorganizes it, and writes it to another file. It also updated the files when other versions of the test were run. By this time I had written several command files that worked together to greatly facilitate the entire benchmark testing procedure. These files are attached to the back of this report for your examination.

B. To deal with my second project, drawing and simulating pre-designed electronic circuits, I had a change of equipment. I used the Zenith Data Systems personal computer, employing two software packages, one to draw the circuit and one to simulate the circuit. They were entitled OrCAD and Pspice, respectively. An engineer worked with me on the project, and had several circuit designs (on notebook paper) that he wanted me to draw and test. There were four circuits in all: a boost converter, a buck converter, a flyback converter, and a two-stage amplifier. First I took the original circuit design and, using the OrCAD utility, drew the circuit on the computer. After this was done, I transferred the data to the Pspice

utility and programmed it to simulate the specific circuit. Many times the simulation showed that the circuit did not produce optimum results because of an error either in the initial design or in the computer drawing. I would then work with the engineer until we solved the problem and ran a simulation with optimum results. The designs would then be taken to another area where they could be examined and retested, and it would then be decided whether they were good enough for actual fabrication.

IV. Results

During my two major projects at the WRDC Electronics Technology Laboratory, I learned a great deal. First, I added a new programming language, DCL, to my repertoire. I also learned many of the "tricks of the trade" of computer programming. Specifically, I learned how to set up several types of loops, use variables and their syntax to achieve the desired results, and open and read several types of files. The data from the VHDL benchmark tests that I ran, after I automated the entire system on the Intermetrics Corporation's product, will also be very useful. The government now has the needed information on that company's product, and is better able to determine which toolset (previously described) to purchase. Also, the automating programs work well, and should prove very valuable.

When I drew and simulated four different types of circuits, I also acquired much information and made several important observations. I learned a great deal about electronics, a branch of science I had not previously been exposed to. I learned what capacitors, inductors, resistors and diodes are, and what their functions are. I observed how several types of converters work to step current up or step current down. I also learned how amplifiers work and several of their functions. Another important result was the data that I developed for the government. These data included the workings of the four circuits I drew and tested. Data on

voltage and current output was determined, as was the actual inner workings of the circuits themselves. The government can now research these four designs to determine if it's desirable to actually fabricate them.

V. Other observations and lessons learned

This summer I learned several interesting things and had new experiences in the Computer Aided Design laboratory. First and foremost, I learned what computer aided design is and its many uses. It can certainly be used to simply draw pictures and logos for various purposes, but its most important function is that of reproducing circuits and simulating them. Along with computer aided design, I learned about a similar subject, VHDL (VHSIC hardware description language), and how it fits into the scheme of computer technology. I gained a degree of familiarity with three different disk operating systems, specifically DOS, VMS, and Unix. I also gained some different, more intangible knowledge, such as how to work well with others, do projects for the betterment of the working group, and meet deadlines. I observed how different the working world is from school, and how you are expected to do your part and act as an adult would. This is perhaps the most important knowledge I gained over the summer.

VI. Bibliography

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8. VMS - General User DCL Dictionary , copyright 1988, Digital Equipment Corporation.

```
$! MASTER CONTROL FILE TO RUN VHDL BENCHMARKS:
$!
$ start:
$ count=0
$ open example ex.txt
$ open/write opfile op.com
$ loop:
$    count=count+1
$    if count .eq. 1 then goto skipper
$    synchronize test
$    @udisk2:[odell.vbm]data.com
$    skipper:
$    read/end_of_file=endit example line
$    tnumf=f$extract(0,3,line)
$    tnum =f$edit(tnumf, "collapse")
$    tdirf=f$extract(4,20,line)
$    tdir =f$edit(tdirf, "collapse")
$    tparf=f$extract(25,10,line)
$    tpar =f$edit(tparf, "collapse")
$    tbinf =f$extract(38,5,line)
$    tbin =f$edit(tbinf, "collapse")
$    tnof =f$extract(38,1,line)
$    tno = f$edit(tnof,"collapse")
$    tplaf=f$extract(44,10,line)
$    tpla =f$edit(tplaf, "collapse")
$    write opfile "$ set def [odell]"
$    write opfile "$ purge test*.*"
$    write opfile "$ set def [odell.vbm]"
$    write opfile "$ delete test*.*.*"
$    write opfile "$ copy udisk9:[vbm.coms''tdir']test.com udisk2:[odell]testn.com"
$    write opfile "$ @ecom"
$    write opfile "$ copy udisk2:[odell]test.com [odell.vbm]test.com
$    if (tnum .eqs. "1") .or. (tnum .eqs. "2") then goto new
$    write opfile "$ sim gen/param="+""""udisk9":[vbm.bench"+tdir+"]shell''tbin'"",",""""test.vhd"",",""+tpar
$    goto new2
$    new:
$    write opfile "$ sim gen/param="+""""udisk9":[vbm.bench"+tdir+"]shell''tbin'"",",""""test''tno'.vhd"",",""+tpar
$    new2:
$    write opfile "$ submit/noprinter/queue=etd2$vhdl/notify/log=[odell.vbm.logfiles]''tnum'tst''tpla'.log test"
$    write opfile "$ exit"
$    close opfile
$    type op.com
$    say "Test ''tnum' in progress..."
$    @udisk2:[odell.vbm]op.com
$    delete op.com;*
$    open/write opfile op.com
$ goto loop
$ endit:
$ close example
$ close opfile
$ purge
$ endt:
$ synchronize test
$ @udisk2:[odell.vbm]data.com
$ exit
$! FILE TO CREATE TEST INFO SOURCE FILE (EX.TXT) FOR READING BY MASTER.COM
$!
$ set def [odell.vbm]
$ place1:
$ count=0
$ delete ex.txt.*
$ open/write op ex.txt
$ purge reinitialize.com
$ open/read/write logi reinitialize.com
$ open/write log reinitialize.com
$ loop0:
```

```
$   read/end_of_file=end0 logi line0
$   if f$extract(0,5,line0) .eqs. "$exit" then goto skipwrite
$   write log line0
$   skipwrite:
$ goto loop0
$ end0:
$ inquire/nopunc len "How many tests are to be run? :  "
$ if len .eqs. "" then goto end0
$ loop1:
$   if count .eqs. len then goto endit
$   count = count + 1
$   place2:
$   verify = 0
$   he = 0
$   inquire/nopunc numf1 "Which test is to be run? :  "
$   if numf1 .eqs. ""
$   then
$   gosub gosub1
$   goto place1
$   endif
$   numf1 = f$edit(numf1,"compress")
$   numf = numf1 + "              "
$   num = f$extract(0,4,numf)
$   dirf = f$trnlnm("dir''numf1'","bench")
$   x = dirf
$   binf = f$trnlnm("bin''numf1'","bench")
$   y = binf
$   if dirf .nes. ""
$   then
$      verify = 1
$      goto skipdir
$   endif
$   place3:
$   inquire/nopunc dirf1 "Enter directory name of test ''numf1' after vbm.bench : "
$   if dirf1 .eqs. "" then goto place2
$   dirf = f$edit(dirf1,"compress")
$   skipdir:
$   dir1 = dirf + "                                              "
$   dir = f$extract(0,21,dir1)
$   if he .eq. 1 then goto place4
$   if binf .nes. "" then goto skipbin
$   place4:
$   inquire/nopunc binf1 "Enter filename after shell of test ''numf1'(ex= 1.sh) : "
$   if binf1 .eqs. "" then goto place3
$   binf = f$edit(binf1,"compress")
$   skipbin:
$   bin1 = binf + "     "
$   bin = f$extract(0,6,bin1)
$   there = f$search ("udisk9:[vbm.bench''dir']shell''binf'")
$   if there .eqs. ""
$     then say "No such file or directory, please enter again...
$     he = 1
$     goto place3
$   endif
$   if x .nes. "" then goto skipdir2
$   inquire dirreq "write to logical table? (Y/N)"
$   dirreq = f$edit(dirreq,"upcase,collapse")
$   if dirreq .nes. "Y"
$   then
$     goto place5
$   else
$     verify = 1
$   endif
$   write log "$define/table=bench ""dir''numf1'"" ""''dirf'"" "
$   define/table=bench "dir''numf1'" "''dirf'"
$   skipdir2:
```

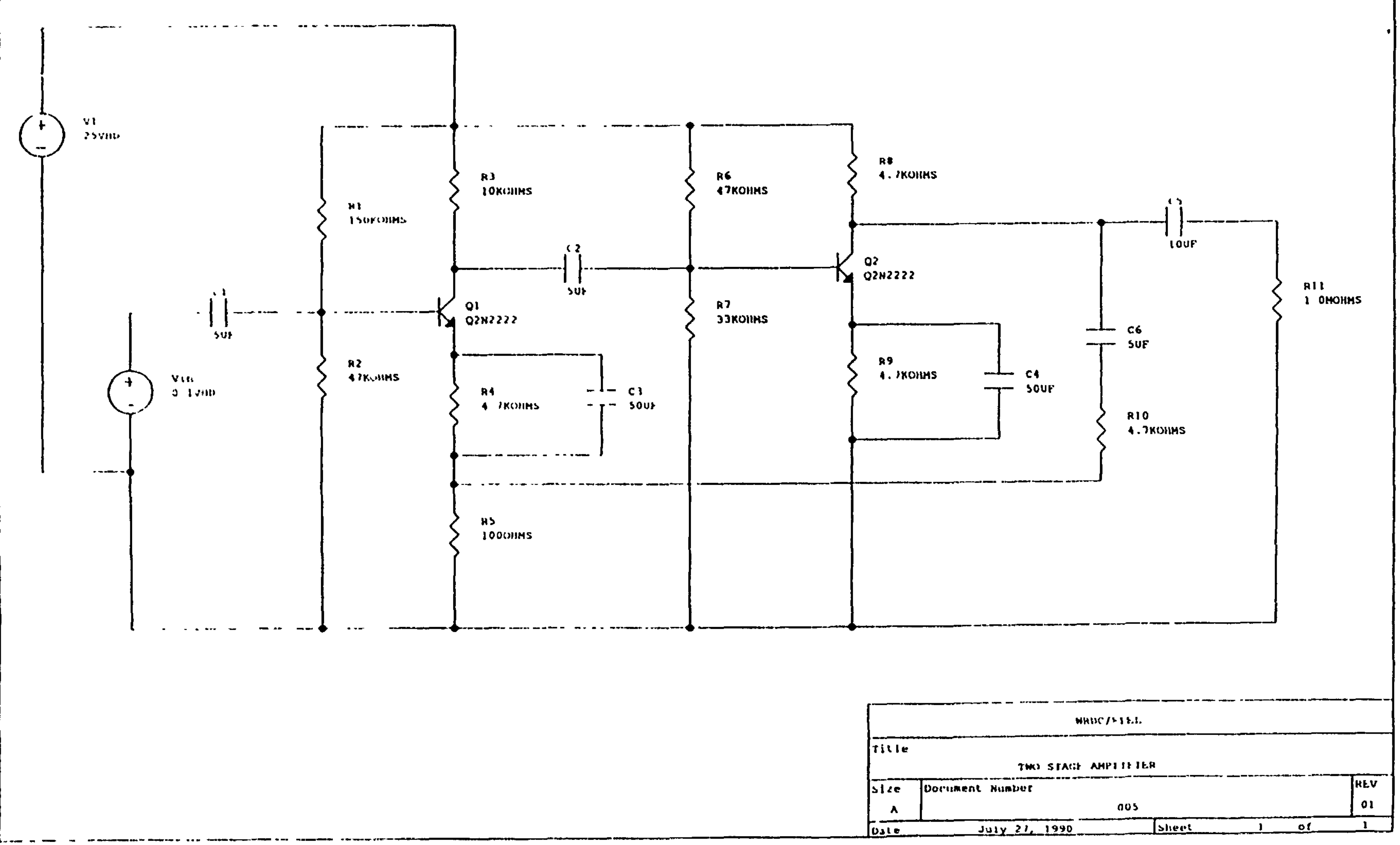
```
$    if y .nes. "" then goto place5
$    write log "$define/table=bench ""bin''numf1'"" ""''binf'"" "
$    define/table=bench "bin''numf1'" "''binf'"
$    place5:
$    c2 = 0
$    inquire/nopunc ver "How many versions of test ''numf1' will be run? :  "
$    if ver .eqs. ""
$    then
$       if verify .eq. 1 then goto place2
$       bin = ""
$       dir = ""
$       goto place3
$    endif
$    loop2:
$       if c2 .eqs. ver then goto end2
$       c2 = c2 + 1
$       place6:
$       inquire/nopunc parf1 "enter parameters of test ''numf1'(with commas) : "
$       parf = f$edit(parf1,"compress")
$       if parf .eqs. "" then goto place5
$       parf = parf + "                    "
$       par'c2' = f$extract(0,13,parf)
$       abort2:
$       log = par'c2'
$       con = 0
$       lp4:
$         ul = f$locate(",",log)
$         if ul .eq. f$length(log)
$         then
$           log'c2' = f$edit(log,"collapse")
$           goto xlp4
$         endif
$         log = log - ","
$         part1 = f$extract(0,ul,log)
$         part2 = f$extract(ul,20,log)
$         log = part1 + " " + part2
$         log'c2' = f$edit(log,"collapse")
$         con = con + 1
$         if con .eq. 10 then goto xlp4
$       goto lp4
$       xlp4:
$    goto loop2
$    end2:
$    cn = 0
$    lp5:
$       if cn .eq. ver then goto xlp5
$       cn = cn + 1
$       write op "''num'"+"''dir'"+par'cn'+"''bin'"+log'cn'
$    goto lp5
$    xlp5:
$ goto loop1
$ endit:
$ write log "$exit"
$ close op
$ close logi
$ close log
$ say "New information file created:"
$ say ""
$ ty ex.txt
$ exit
$ gosub1:
$ count = 0
$ close logi
$ close log
$ close op
$ return
```

```
$create/name_table bench
$define/table=bench "dir7" ".A.C"
$define/table=bench "bin7" ".SH"
$define/table=bench "dir1" ".A.C.F3.I1"
$define/table=bench "bin1" "1.SH"
$define/table=bench "dir5" ".B.C.K.L1.M"
$define/table=bench "bin5" ".SH"
$define/table=bench "dir6" ".B.C.K.M"
$define/table=bench "bin6" ".SH"
$define/table=bench "dir12" ".B.C.S2"
$define/table=bench "bin12" ".SH"
$define/table=bench "dir13" ".A.C.H2.L3.S2"
$define/table=bench "bin13" ".SH"
$define/table=bench "dir50" ".A.C.I2.P2"
$define/table=bench "bin50" "1.SH"
$define/table=bench "dir58" ".B.C.P8"
$define/table=bench "bin58" "0.SH"
$define/table=bench "dir59" ".B.C.K.L1.P8"
$define/table=bench "bin59" "0.SH"
$exit
$! FILE TO ADAPT TEST.COM FILE TO ENVIRONMENT BEFORE RUN
$!
$ set def [odell]
$ open/write test test.com
$ open/read testn testn.com
$ write test "$ set def udisk2:[odell.vbm]"
$ read testn fil
$ loo:
$   read/end_of_file=next testn filin
$   write/symbol test filin
$   goto loo
$ next:
$ write test "$ set noverify"
$ close test
$ close testn
$ delete testn.*.*
$ set def [odell.vbm]
$ exit
$! ASSOCIATED BENCHMARK FILE TO EXTRACT .LOG FILE INFORMATION
$!    (CPU TIMES FOR SEPARATE SECTIONS OF TEST)
$!
$ open/read inp [odell.vbm.logfiles]'tnum'tst'tpla'.log
$ iff = f$search("udisk2:[odell.vbm.data]data''tnum'.dat.*")
$ say "Writing logfile output to data file..."
$ yes = 0
$ if iff .eqs. ""
$ then
$   yes = 1
$   gosub makefile
$ endif
$ open/read oup [odell.vbm.data]data'tnum'.dat
$ open/write newop [odell.vbm.data]data'tnum'.dat
$ lp1:
$   read/end_of_file=end1 oup lines
$   write newop lines
$ goto lp1
$ end1:
$ set def [odell.vbm.data]
$ close oup
$ purge/keep=1
$ set def [odell.vbm]
$ cnt=0
$ c3 = -1
```

```
$ write newop "   PARAMETERS = ''tpar' "
$ lp2:
$   read/end_of_file=end2 inp info
$   chk = f$extract (0,1,info)
$   if chk .eqs. "$"
$   then
$     cnt=cnt+1
$     if cnt .eq. 1 then goto skip0
$     coml= f$extract(2,30,info)
$     com = f$edit(coml,"trim,compress")
$     if com .nes. "sh proc/acc"
$     then
$       com = com + "                                   "
$       com = f$extract(0,25,com)
$       real = com
$     endif
$     delete/sym com
$   skip0:
$   endif
$   chck = f$extract(9,3,info)
$   if chck .eqs. "CPU"
$   then
$     c3 = c3 + 1
$     timel=f$extract(32,5,info)
$     if cnt .eq. 1 then goto skip
$     ln = f$length(timel)
$     lnd = f$length(dummy)
$     tim2 = f$integer(timel - ".")
$     dum2 = f$integer(dummy - ".")
$     timl = tim2-dum2
$     ti'c3' = 'timl'
$     lnt = f$length(timl)
$     tima = f$string(f$extract(0,lnt-2,timl))
$     timb = f$string(f$extract(lnt-2,2,timl))
$     time = tima+"."+timb
$     skip:
$     dummy = timel
$     if cnt .eq. 1 then goto skip3
$     set def [odell.vbm.data]
$     write newop "''real' : ''time'"
$     set def [odell.vbm]
$     skip3:
$   endif
$   chckk = f$extract(8,4,info)
$   if chckk .eqs. "d CP"
$   then
$     total = f$extract(32,5,info)
$     real2 = "Charged CPU time" + "                                "
$     real2 = f$extract(0,25,real2)
$     final = 0
$     c4 = -1
$     ti0 = 0
$     nested:
$       c4 = c4 + 1
$       if c4 .eq. c3+1 then goto leave
$       final = final + ti'c4'
$     goto nested
$     leave:
$     final2 = "Total CPU time" + "                               "
$     final2 = f$extract(0,25,final2)
$     lnf = f$length(final)
$     finale1 = f$string(f$extract(0,lnf-2,final))
$     finale2 = f$string(f$extract(lnf-2,2,final))
$     finale = finale1+"."+finale2
$     write newop "''final2' : ''finale'"
$     write newop "''real2' : ''total'"
```

```
$   endif
$ goto lp2
$ end2:
$ write newop ""
$ close inp
$ close newop
$ exit
$ makefile:
$ open/write new [odell.vbm.data]data'tnum'.dat
$ write new "      DATA INFO on TEST ''tnum'  (CPU time, in seconds)"
$ write new ""
$ close new
$ return
```

TWO STAGE AMPLIFIER



Electron Beam Lithography

apprentice: Suzette Yu
mentor: Ed Davis
Electronic Technology Laboratory
August 27, 1990

I. Acknowledgements

I would like, of course, to thank Ed Davis for the time he spent with my fellow apprentice and I, as well as for his affability and receptiveness to questions. This also applies to the numerous people who put aside their own tasks to answer my inquiries on everything from lexical functions to the clean room deionized water tanks.

II. Introduction

The transistor has emerged as the key to both defense weaponry and the elaborate supercomputers which will dominate the future. Although traditional silicon devices suffice for today's electronics, engineers seek to perfect more advanced transistors for use in sophisticated systems not yet developed. This cutting-edge technology focuses on the compound gallium arsenide (GaAs) due to its high-speed capabilities; the potential of GaAs has prompted labs around the world to allocate time, manpower, and resources to researching this promising field.

Of the various processes necessary to the creation of a device, electron beam lithography plays an essential role since it deals with transistor design, an integral consideration in effectiveness. Use of electron beam lithography introduces not only the challenge of developing feasible patterns, but also problems associated with the nature of the equipment. This

presents only one obstacle in the formation of the GaAs transistor.

III. Gallium Arsenide (GaAs) Technology: An Overview

The fabrication of GaAs transistors involves various processes, perhaps little known but essential to the completion of a high-quality device. Among these techniques are GaAs crystal growth, epitaxy and ion implantation, etching, and lithography. To begin, the engineer needs slices of material; generally a manufacturer accomplishes this through one of two means: horizontal Bridgeman (HB) or liquid encapsulated Czochralski (LEC). In HB, a so-called "boat" filled with either gallium or polycrystalline gallium arsenide and a seed crystal is placed in an enclosed chamber with pure arsenic at the head of the area. Using heat, this set-up effects a reaction between the two elements, causing crystal growth as the high-temperature region moves down the boat. By contrast, the LEC method involves vertical growth of crystals; a crucible serves as a container for liquid GaAs covered by a boric oxide crust. After a seed crystal descends through the upper layer to the gallium arsenide, machinery raises it upwards to form a crystal. At the completion of either of these processes, individual wafers are sliced off.

Yet this step represents only the beginning of the technology involved. Once the lab receives its GaAs wafers, it must prepare them for further work by adding various layers;

engineers employ epitaxy or ion implantation for this purpose. The three types of epitaxy -- liquid phase (LPE), vapor phase (VPE), and molecular beam (MBE) -- each complete this step. The first of these, LPE, is becoming obsolete due to its failure to produce consistent layers. After the GaAs substrate is placed in a receptacle which permits sliding, it is moved across various pools of molten material from which atoms solidify onto the crystal. Slightly superior to the above method, VPE utilizes vapors which converge onto the GaAs substrate in a closed system. Far more precise than both these methods is molecular beam epitaxy, which yields a uniform layer of a desired thickness and any amount of doping. In an extremely high vacuum, heated elements emerge from different ovens, called effusion cells, and reach the rotating substrate. Only the massive technical difficulty and thus the expense of MBE machines hinders this accurate process from widespread use. However, not all laboratories even use a type of epitaxy; many utilize ion implantation, a popular and established means of producing the desired layers. In this procedure, atoms invade and disturb the GaAs crystal structure but then are drawn into a more uniform layout through a high-temperature process known as annealing. Either ion implantation or epitaxy may fulfill the requirement for creating the needed layers.

After the completion of this step, the material undergoes some form of etching: wet or dry. Wet etching involves the use of chemicals which act as reducing agents on the surface and then dissolve it. Although masking substances are used to protect

certain areas, the etchant usually undercuts this material. To alleviate this problem, dry etching is employed. Under this category fall the vaguely defined subdivisions of plasma etching, reactive ion etching (RIE), reactive ion beam etching (RIBE), and ion milling. Plasma etching involves the initiation of chemical processes whose products complete the etching process; RIE utilizes plasma but also strengthens its reactions through the energy of the ions which reach the surface. To continue the string of similarities, RIBE acts much as RIE except that a grid placed beteen the plasma and wafer accelerates ions from the former; and with ion milling, gaseous ions bombard the slice to wear away its surface. In sum, many methods can accomplish etching.

Yet another process, lithography, creates patterned areas of exposure on the resist that covers the slice; subsequently, either the exposed or unexposed resist is dissolved. The two major types of lithography, photo and electron beam, enjoy use for this purpose. In the case of photolithography, several procedures have faded due to the emergence of optical steppers. Unlike older methods which either damaged the mask or demanded a flawlessly flat wafer, the optical stepper consists of a mask, termed a reticle, which holds a sole image that it projects onto numerous slices which run by it. However, all techniques mandate a vibration-free environment due to the minuscule dimensions involved. Yet GaAs technology sometimes requires even tinier measurements which light's wavelength cannot accomodate. In these cases, electron-beam lithography serves well; inside a

high-vacuum chamber, electrons hit the wafer in a computer-controlled pattern. Both photolithography and e-beam remain popular. In conclusion, each of the varied processes involved in forming GaAs devices opens a new realm of different methods which continue to evolve.

IV. Electron beam (e-beam) Lithography Procedures

Conducting design research with the e-beam consists of numerous steps, the first of which considers determining the specifications of the pattern to be written. As with any scientific experiment, this process requires analyzing problems with previous attempts and attempting to pinpoint the culprit: an overly high dosage, for instance. Pattern creation follows. In a language such as JEOL01, the revised pattern is programmed into the computer that controls the e-beam; during this time, the GaAs wafer is coated with layers of resist and loaded into the lithography machine. After calibration and focus of the computer, the e-beam draws the desired designs onto the slice, which is then removed and developed by squirting various solvents onto the wafers. By dissolving the different types of resist, these liquids allow the emergence of the transistor gate, which is viewed first on an optical microscope to gain a general idea of the write's quality. Following the placement of a gold film on the wafer, the gate pattern can be inspected with a scanning

electron microscope, which permits a precise evaluation due to its high magnification ability. Thus, the task commences again; the analysis of one write leads to plans for the next.

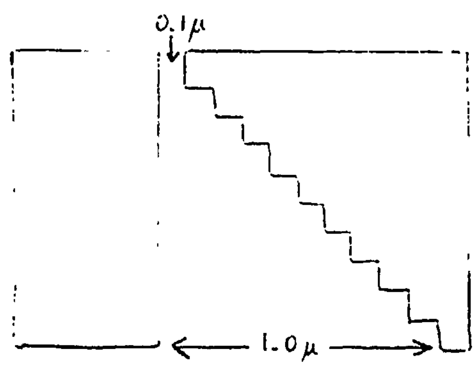
V. Proximity Patterns

A problem encountered in developing patterns is that of electron backscattering. When the beam strikes the wafer, the energy of the particle never remains confined to exactly the same spot; instead, the electrons bounce around, resulting in an exposed area greater than that of the beam itself. This becomes a pressing consideration when dealing with exceptionally minute dimensions since slight error may destroy the pattern. For instance, the exposure of two lines close to one another may cause resist between them to be affected as well. In addition, a recent proposal to create a pattern that consists of a series of slender rectangles set very near each other deals with this proximity effect. If this design is to be implemented in radar receivers as planned, scattering must be accounted for; other patterns mandate this as well.

However, the peculiar circumstances in the situation prevent simple library work from sufficing. Although a laboratory across the country may have performed proximity effect experiments, their specified conditions probably could not be reproduced due to differences in machinery, environment, resist, and other factors. Thus, a lab must determine the best means to alleviate

the negative effects of proximity for its individual set-up. Further compounding the problem is the fact that even the same laboratory may experience day-to-day variations in e-beam writes.

Despite these hindrances, a certain degree of accuracy can be achieved. In this case, a pattern to test the extent of the scattering was developed; it consisted of a stairstep design, as follows:



Since the distance between the lines increased by increments of 0.1 micron, the pcint at which the proximity effect became pronounced could easily be spotted.

After the pattern was projected numerous times ont afers, each copy having a different dosage, the resulting images proved satisfactory; error-ridden attempts eventually yielded a majority of patterns precisely drawn even to the 0.1 micron range. Although these results did not follow through to the extremes of excessively high and low doses (for example, with smaller doses, parts of the pattern did not even appear), the specifics of the experiments may be applied in future designs that will certainly require control of proximity effects.

V. Closing Remarks

The research concepts learned this summer apply not only to the Electronic Technology Laboratory and to the field of GaAs transistors, but also to scientific endeavors as a whole. Ultimately, the intangible asset of exposure to the workings of engineering will prove more valuable than knowledge of any hard facts or detailed procedures.

VI. Reference

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FLIGHT DYNAMICS LABORATORY

High School Apprenticeship Program Final Report

Jean Ay

Mentor: Larry Coulthard

Flight Dynamics Laboratory

August 10, 1990

I wish to express sincere thanks to everyone who made this program such a wonderful experience for me. I would like, first of all, to thank my mentor, Larry Coulthard, for everything he did to help me. I would also like to thank Kurt Lee, Chris Blasy, Rick Peters, Ron Studebaker, Alex Kurtz, and Carole Patrick and everyone else at the Survivability Enhancement Branch who took the time to teach and to encourage me.

The branch that I worked with, the Survivability Enhancement Branch, operates the gun range facilities. They specifically test the survivability and vulnerability of an aircraft and its components to various threats. I was able to observe and to participate in much of the testing. Mostly, I worked on two separate programs. In between these programs, I undertook numerous other miscellaneous tasks. I found that some of what I encountered, I had been previously exposed to. However, the majority was entirely new to me.

In the primary program, I was involved with, it was necessary to ascertain the kinetic energy of fragments at varying velocities. This was done by shooting fragments of six different masses at bundles of drywall panels at several velocities. The number of panels damaged was recorded, any damage to the fragment was noted, and velocities were also calculated. All of this information was later compiled onto a spreadsheet and graphed.

In another program, composite panels of graphite epoxy were tested and compared to aluminum panels. Because the composite material is lighter in weight than aluminum, it is hoped that it can replace the use of aluminum in aircraft. These composite panels were shot at various velocities and were instrumented to calculate strain. The amount of damage

was also observed. All of this test information was kept on hard disks to be analyzed later.

This program has undoubtedly been a worthwhile experience for me. I did, at times, have trouble finding enough work to keep me occupied, because the program I was mainly involved with progressed rather sporadically. However, I was given a large amount of antonomy in pursuing and completing my work. I found that to be very challenging. I also gained valuable experience in working with others. I discovered that engineering included not just research and experimentation, as I had expected, but it also included financial concerns, presentations, and much report routing. During my interim at the Survivability Enhancement Branch, I learned many expected and many unexpected things.

Project "Environmental Reliability":
The Analysis of Printed Circuit Boards

Apprentice: Matt Becker
Mentor: Amar Bhungalia
Flight Dynamics Lab
August 10, 1990

Acknowledgments

I would like to thank my mentor Amar Bhungalia for providing my first look at the world outside of books and school. Whenever I had a question about anything Amar would force me to work out the answer on my own. Again I am grateful for the time and effort he spent being my guide through my eight weeks at Wright-Patterson Air Force Base.

Also I must express my sincere gratitude to Ron Gould whose extensive knowledge of computers and electronics helped me at every turn. In answer to my queries he provided clear, concise answers that often went beyond the scope of what I had asked. I am thankful for the opportunity to work with such an inteligent and interesting man.

Finally I want to thank George Kurylowich and my fellow employees for answering all of my other questions and for providing me with invaluable information related to a variety of colleges and careers which I can now explore in depth. I have learned enough here at the Flight Dynamics Lab to keep my curiosity sparked for the rest of my life and I hope to repeat the experience.

In recent years, the need for increased manueverability, speed, and precision has forced pilots to rely more and more on the electronic aides and safeguards incorporated into aircraft. As a pilot's dependence on electronic gadgetry increases, so does the responsibility of producers to provide more reliable equipment. The defense cuts coupled with the fact that the earlier a weakness can be identified the less expensive it is to correct, places the greatest burden on the shoulders of those in the earliest stages of development. Because of their position in development, preliminary designers are the most effective solution to the rectification of avionic's design dificulties. With project "Environmental Reliability" the United States Air Force seeks to identify trends in temperature and vibration related failures, which can be used in other projects to design avionics equipment which survives extended periods of high level stress. Not only does this project provide needed guidlines for avionics design, it also insures that problems common to avionics are known in the earliest stages of development.

One important piece of avionics equipment being studied is the line replacable unit (LRU), a rectangular box which holds printed cicuit boards (PCBs) and provides temperature modulation and protection against vibration. Bircher guides, the typical slide in guide, or wedge-lock guides, which utilize screw down supports, are commonly used to connect the circuit boards to the LRU. These guides serve as a path for escaping heat to follow, support to lessen detrimental vibration, and easy access. Wedge-lock guides tend to be better guides when it comes to thermal and vibrational considerations, while the more common Bircher guides provide easier accesses. Pin connectors, which link the circuit boards to the rest of the avionics system, provide rigidity to

the PCB much like the two side guides. Since the excess heat generated by PCB components eventually leads to thermal failure, it is necessary to prevent overheating. In a "Cold" wall LRU, the PCBs remain cool through a heat exchange with air or liquid passing along the walls of the unit. Air coolant has proven to be the easier system to maintain because minor leaks do not result in electrical shock. In order to provide extra surface area which leads to a more efficient heat exchange, designers sometimes employ "honeycomb" walls, where coolant passes through small tubes imbedded within the walls. Another consideration in LRU design is the amount of vibration translated to the PCB. A vibration isolated LRU successfully lessens the amount of vibrational stress with high frequencies, but proves less successful with high defamation stresses and over extended periods of use, while the rigidly mounted LRU provides a solid mount that lasts longer. The LRU's central purpose is to dampen the detrimental conditions that seek to destroy PCBs.

The printed circuit board, another element of avionics equipment, holds the components which perform the operations and calculations that are so important to a pilot. The circuit board consists of numerous layers and components. One such layer, the heatsink, provides temperature regulation. This layer, made up of thermally conductive metal, absorbs the heat generated by the components on the PCB surface and transfers it to the LRU walls. This process keeps the circuit board and components from overheating during periods of use. One central problem faced with heatsinks is their tendency to expand and warp when carrying large amounts of heat. Though the board returns to its normal position after the heat is removed, continued distortion through heating and cooling leads to the circuit board's eventual failure (figure 1 - 3). This

process is called thermal cycling. I, as a member of project "Environmental Reliability", have investigated the trends found with three of the most common metals used as heatsinks : copper, aluminum, and nickel (fig. 4 & 4a). As a general rule heatsink thicknesses of 0.005 to 0.02 inches result in longer life expectations, while between 0.02 and 0.04 inches the expectations are drastically lower. However, as the thickness continues to increase from 0.04 the life expectations slowly climbs again. With these facts one can conclude that the other circuit board layers, meant to prevent defamation, can withstand the expansion of only up to 0.02 inches of heatsink before collapsing, but after a certain point the heatsink has enough mass to absorb the heat without seriously warping. The best, non-warping conductor studied is copper with a thickness of 0.005 because its predicted component life is 14,750,000 cycles at such a low weight. Nickel takes second because of its high life expectations at higher thicknesses, but the central problem is its weight at thicker levels. While copper and nickel have lives in the millions, aluminum can boast a life of only 24 cycles which makes it, by far, the worst.

In order to compensate for heatsink defamation, printed circuit boards require layers that resist warping. These layers receive their name from the plastic bonding material most commonly used in them : epoxy. To make most epoxy layers with fibers such as mylar, lexan or nylon, one must first prepare a thin square box with tiny holes along its sides. Next, synthetic fibers are tightly stretched across the box so as to remain parallel. Once this is complete, some type of coagulating plastic, usually epoxy, is forced through the side holes as a high temperature liquid. In the final step one slowly cools the newly formed epoxy layer to room temperature by which point the layer

has hardened into a stiff, flat square with coordinate threads. The reason for parallel filaments is that they reinforce one another and can withstand heavier loads in a direction similar to the fibers. However, an epoxy layer will often collapse with even a moderate load, that possesses a direction normal or perpendicular to the fibers, because the pressure is not on the fibers themselves, but rather on the epoxy holding the fibers together. Another use of epoxy is the cementing of layers together. Shear stress, caused by differing thermal expansion rates, can destroy this link between layers much like the perpendicular pressure can do within layers. Also, major problems usually result from asymetrical layering, because one side of the PCB will end up weaker than the other which forces all of the pressure to that side and eventually causes failure. Keeping these facts in mind, project "Environmental Reliability" had me conduct computer analyses to determine which angle ply layup results in the longest life (fig. 5 & 5a). The outcome of those tests shows that for a layered composite PCB with 5 layers including one central heatsink layer, the optimum angles are -45 degrees, -60 degrees, heatsink, -60 degrees, and -45 degrees. These angles work better because the -45 degree angles hamper the expansion away from the pin connectors and the -60 degree angles prevent most warping occuring between the side guides. Amar Bhungalia and I agree that more specific analyses on the nature of epoxy layers are needed including one to determine the best positioning for different types of epoxy layers.

The components mounted on the PCB are one of the most important segments of avionics because they perform the functions that an aircraft needs to fly. They are connected to the PCB by tiny leads with thicknesses averageing only

0.01 inches, which makes them the most fragile piece of avionics. Since the circuit board expands more quickly than its components, the leads receive a lot of pressure which eventually rips them apart (fig. 6). The pressure centers around one of three locations : the mount between PCB and lead (fig. 7), the connection between component and lead (fig. 8), or the bend radius of the lead (fig. 9). In general the mountings types used at the PCB surface consist of two options : surface mounting, in which the lead is soldered to the PCB, and pokethru, in which the lead passes through the whole PCB. In one study I found that surface mounting is less effective than pokethru (fig. 10 & 10a). Knowing the fact that lead material is more flexible than solder, one can reason that in a surface mounted lead, the small solder fillets holding the lead to the PCB, cannot survive the shear stress created by expanding PCB and component. Leadless chip carriers, a new type of component, rest on leads made of solder, which caused it to fail quickly in each of my tests. On the other hand a pokethru lead takes most of the stress on itself, leaving the solder free of pressure. Another location prone to failure is the junction between the lead and its component. Again two types of mountings are employed : side brazed, where the lead is soldered to the outside of the component, and bent, in which the lead actually enters the casing of the component. As with the previous case, the connection tends to be stronger with bent leads, because the lead takes the stress, which leaves the solder virtually stress free. The last area in which leads tend to fail occurs at the bend radius where shear stress builds up. One can easily circumvent this and the other lead failures by reducing the shear stress on the leads.

The results previously described were found with the help of a computer

analysis algorithm. This program first divides the layers, components and leads of a circuit board into tiny sections called finite elements (fig. 11 & 12). The amount of stress in each element is then determined by analyzing the known conditions of each element such as location, material, and temperature. Finally the computer choses the largest amount of lead stress for calculation of component life. The life of one design, expressed in the number of cycles before failure, can then be compared with other designs to determine the better design. I use this program to compare designs which differ in only one way in order to determine the best design features. One major problem encountered is in the fact that this analysis method has not yet been perfected and work on the algorithm itself is needed. Also as with most computer analysis programs, a concern that must be met is the need for experimental data backing up the computer's predictions. Still this computer analysis work is a necessary first step that must be taken in order to successfully accomplish the objectives of project "Environmental Reliability".

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Jul/11/90

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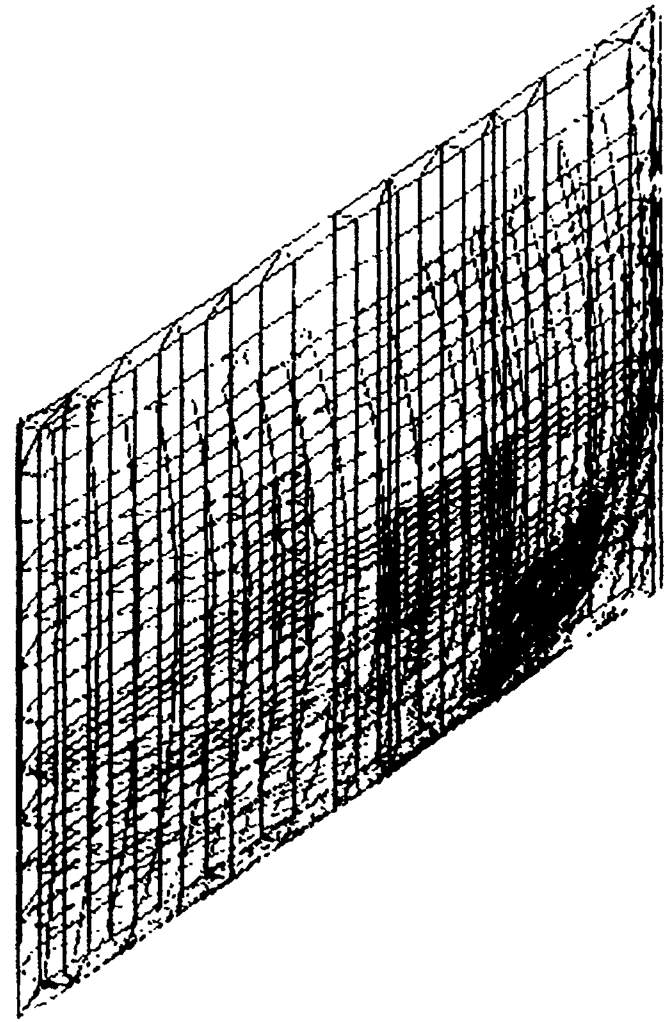


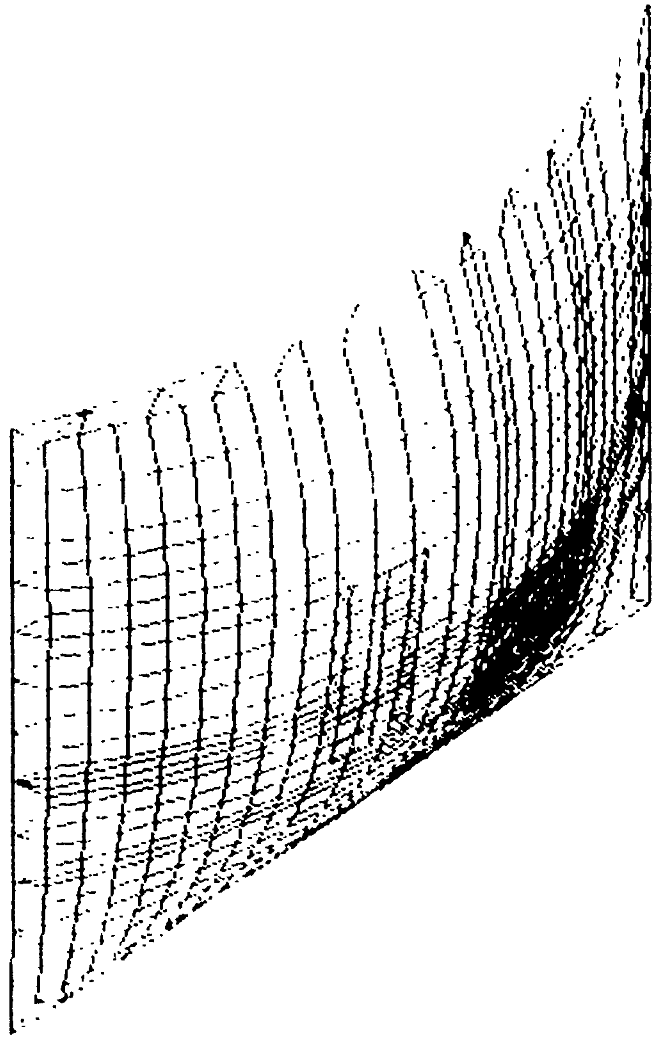
MESH FOR PCB # 11

RX= 45
RY= 45
RZ= 0

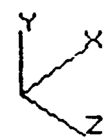
Figure 1

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Jul/11/90

DISPLACED - SHAPE
MX. DEF- 1.08E-01
NODE NUMBER= 306
SCALE = 4.0
(MAPPED SCALING)



MESH FOR PCB # 11



RX= 45
RY= 45
RZ= 0

Figure 2

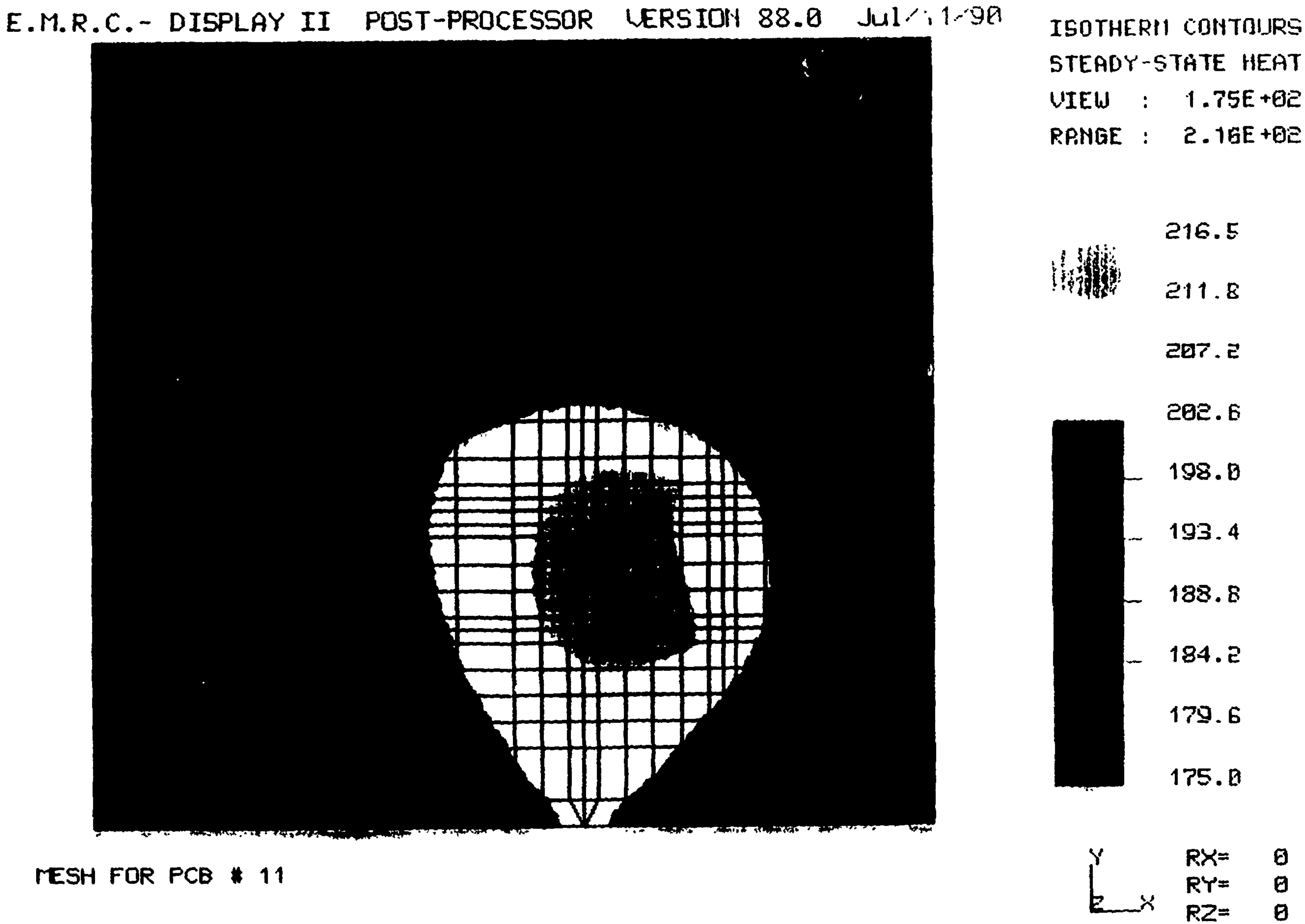
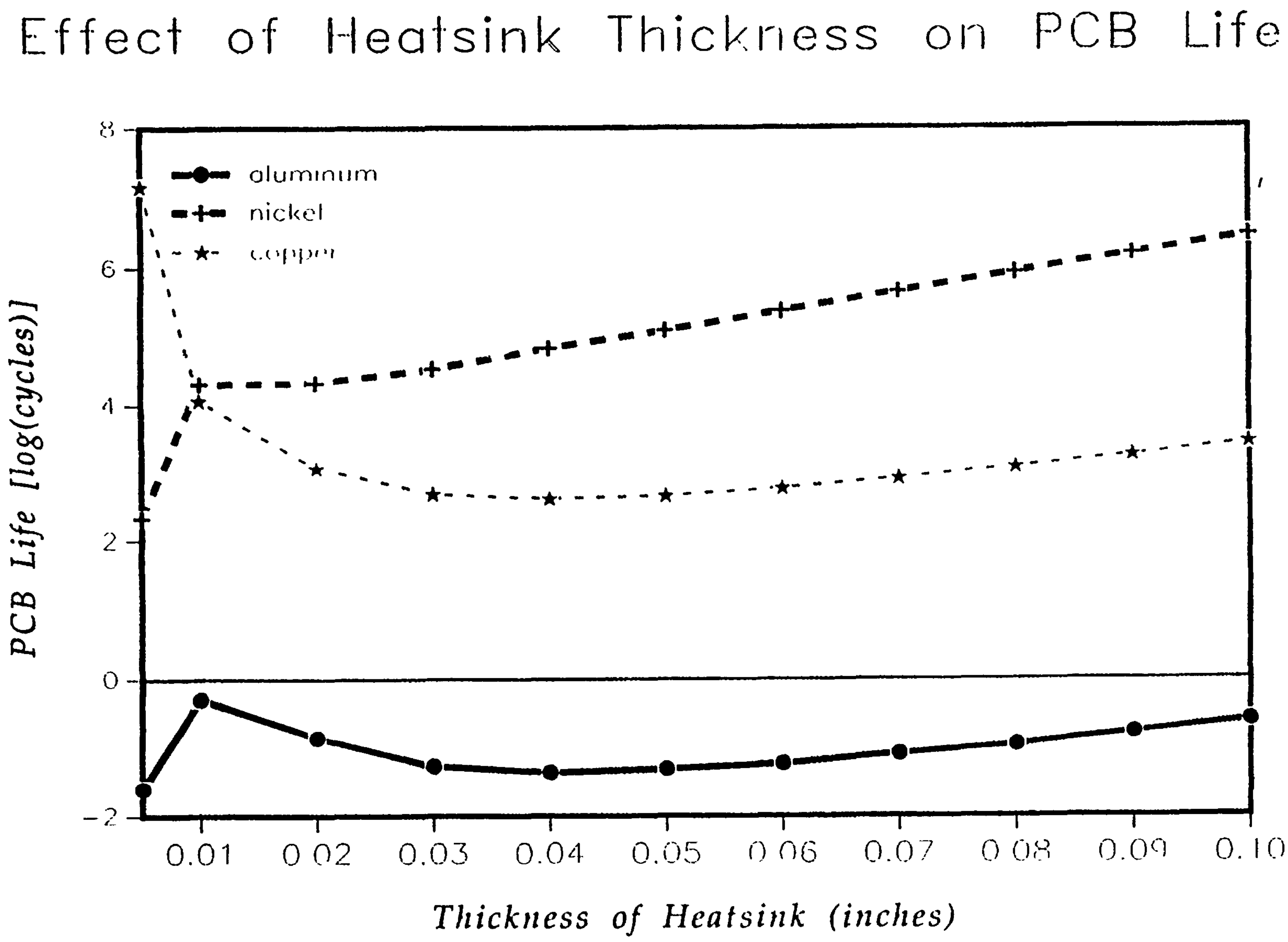

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0
ISOTHERM CONTOURS
STEADY-STATE HEAT
VIEW : 1.75E+02
RANGE : 2.16E+02
216.5
211.8
207.2
202.6
198.0
193.4
188.8
184.2
179.6
175.0
Y
Z
X
RX= 0
RY= 0
RZ= 0
MESH FOR PCB # 11

Figure 3



Effect of Heatsink Thickness on PCB Life
aluminum
nickel
copper
PCB Life [log(cycles)]
8
6
4
2
0
-2
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
Thickness of Heatsink (inches)

Figure 4

Effect of Heatsink Thickness on PCB Life

5-layer	Life (cycles)			Life (log[cycles])		
Sink(")	Cu	Al	Ni	Cu	Al	Ni
0.005	1 475E7	2.485E-2	2.082E2	7.169	-1.605	2.318
0.010	1.182E4	5.049E-1	2.059E4	3.073	-0.297	4.314
0.020	1.159E3	1.381E-1	2.147E4	3.064	-0.860	4.332
0.030	4.772E2	5.411E-2	3.415E4	2.679	-1.267	4.533
0.040	4.073E2	4.404E-2	6.744E4	2.601	-1.356	4.829
0.050	4.493E2	4.916E-2	1.226E5	2.653	-1.308	5.089
0.060	5.729E2	5.860E-2	2.300E5	2.758	-1.232	5.362
0.070	7.894E2	8.052E-2	4.368E5	2.897	-1.094	5.640
0.080	1.150E3	1.080E-1	8.239E5	3.061	-0.967	5.916
0.090	1.738E3	1.622E-1	1.543E6	3.240	-0.790	6.188
0.100	2.639E3	2.429E-1	2.811E6	3.421	-0.614	6.449

Figure 4a

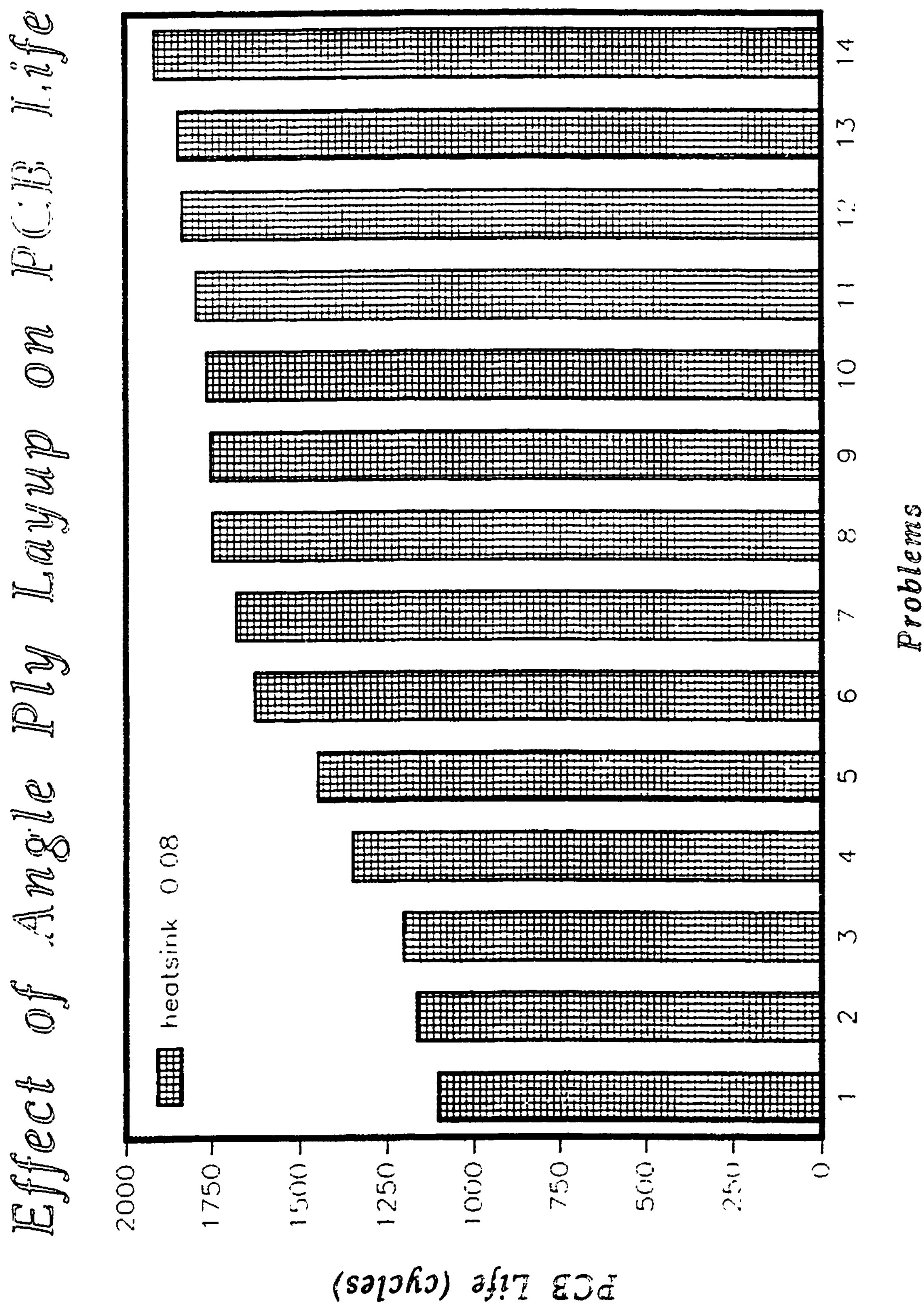

Effect of Angle Ply Layup on PCB Life
heatsink 0.08
PCB Life (cycles)
2000
1750
1500
1250
1000
750
500
250
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Problems

Figure 5

Sink = 0.08	ANGLE MEASUREMENTS IN DEGREES						
PROB	ID#	ANGLE1	ANGLE2	ANGLE3	ANGLE4	ANGLE5	LIFE
1	THR37	30.0	30.0	0.0	30.0	30.0	1107.70
2	THR42	30.0	45.0	0.0	45.0	30.0	1167.00
3	THR34	45.0	45.0	0.0	45.0	45.0	1206.20
4	THR40	60.0	60.0	0.0	60.0	60.0	1348.60
5	THR41	-60.0	60.0	0.0	60.0	-60.0	1448.70
6	THR39	30.0	90.0	0.0	90.0	30.0	1625.80
7	MOD3	60.0	90.0	0.0	90.0	60.0	1679.80
8	MOD2	90.0	-60.0	0.0	-60.0	90.0	1748.10
9	THR33	90.0	90.0	0.0	90.0	90.0	1753.40
10	THR36	-45.0	-45.0	0.0	-45.0	-45.0	1762.80
11	THR43	-30.0	-45.0	0.0	-45.0	-30.0	1794.50
12	THR35	-60.0	-45.0	0.0	-45.0	-60.0	1834.90
13	MOD1	-60.0	90.0	0.0	90.0	-60.0	1847.60
14	THR38	-45.0	-60.0	0.0	-60.0	-45.0	1914.10

Figure 5a

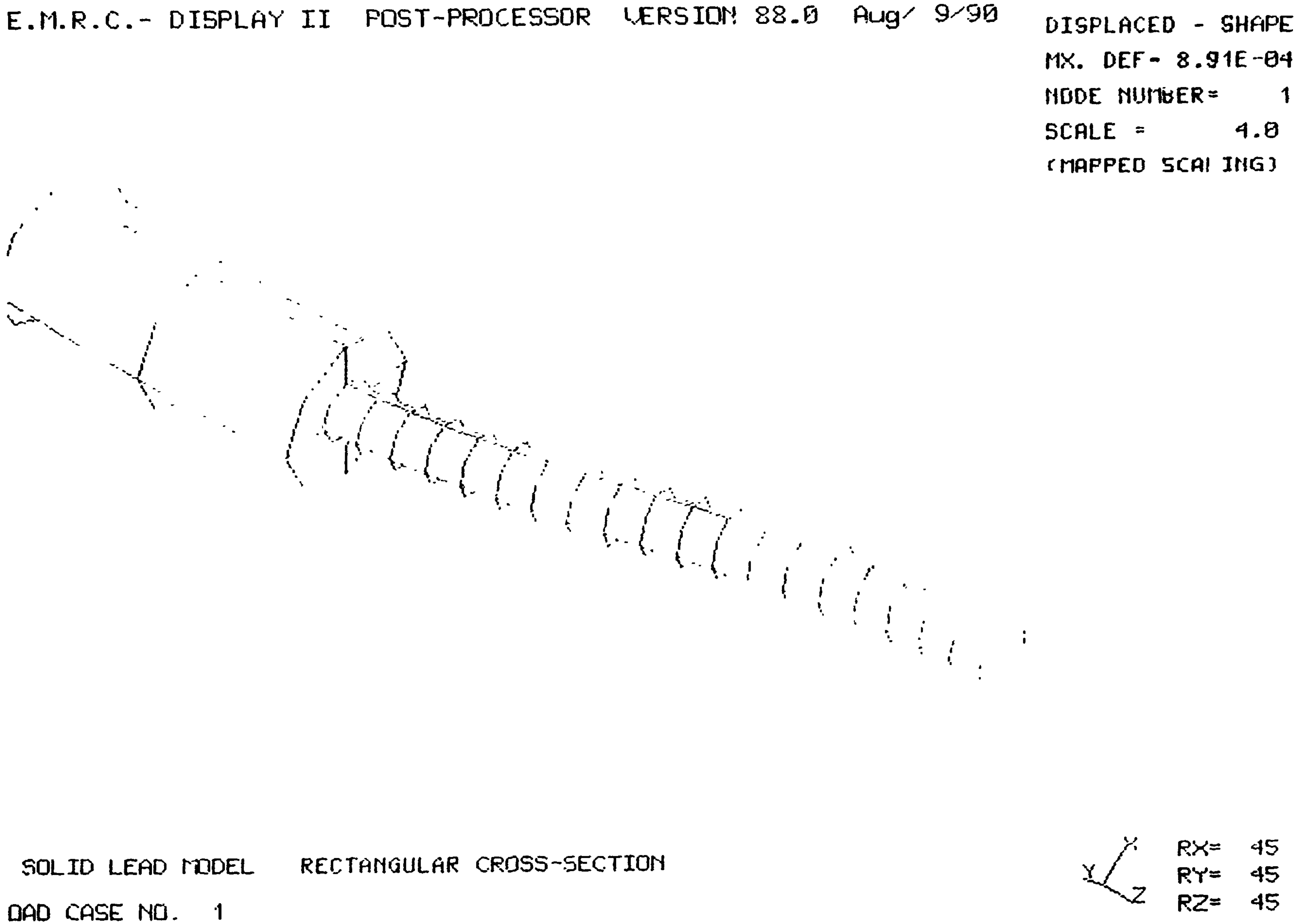

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Aug/ 9/90
DISPLACED - SHAPE
MX. DEF- 8.91E-04
MODE NUMBER= 1
SCALE = 4.0
(MAPPED SCAI ING)
SOLID LEAD MODEL RECTANGULAR CROSS-SECTION
OAD CASE NO. 1
X
Y
Z
RX= 45
RY= 45
RZ= 45

Figure 6

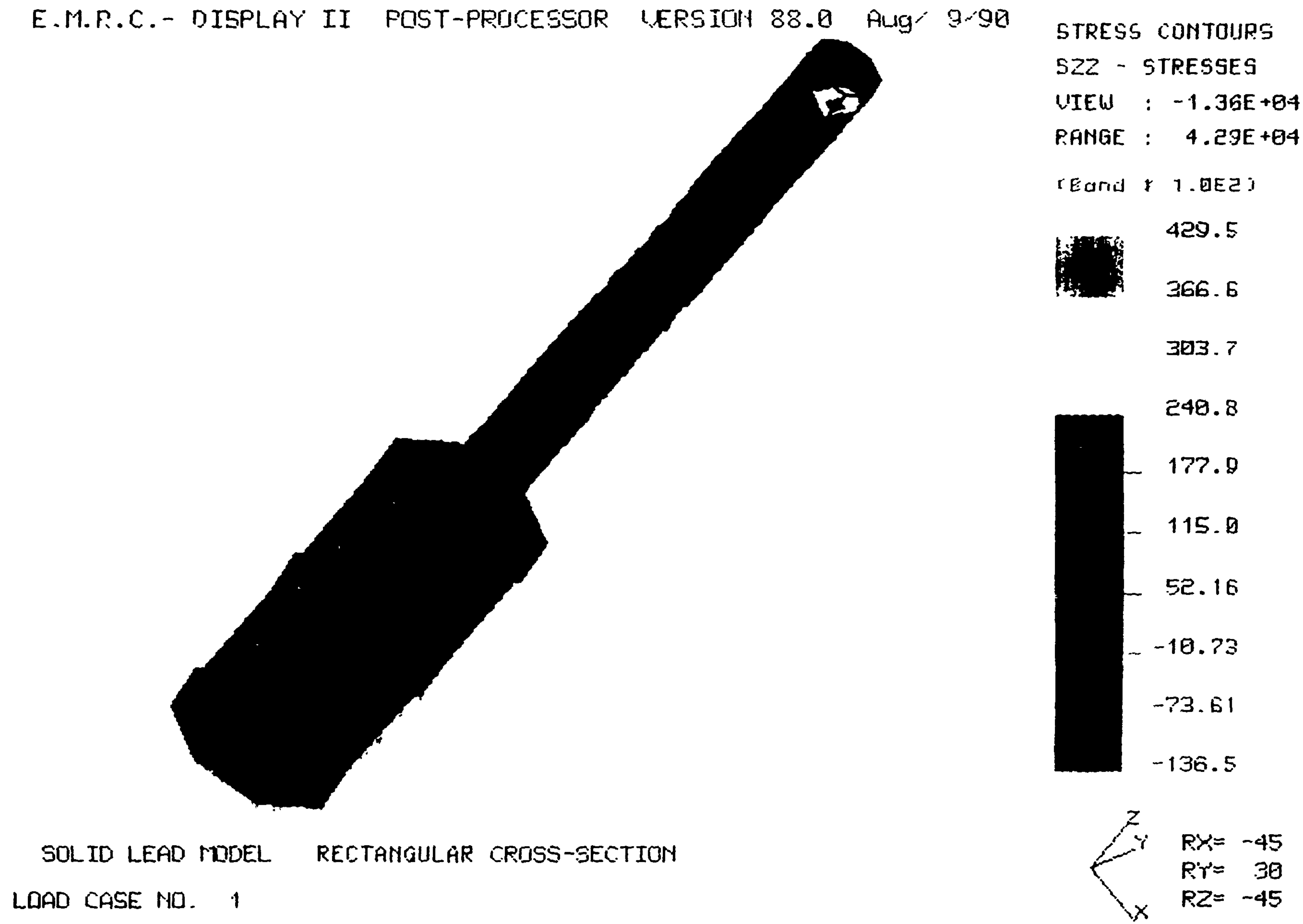

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Aug/ 9/90
STRESS CONTOURS
SZZ - STRESSES
VIEW : -1.36E+04
RANGE : 4.29E+04
(Band * 1.0E2)
429.5
366.6
303.7
240.8
177.9
115.0
52.16
-10.73
-73.61
-136.5
Z
Y
X
RX= -45
RY= 30
RZ= -45
SOLID LEAD MODEL RECTANGULAR CROSS-SECTION
LOAD CASE NO. 1

Figure 7

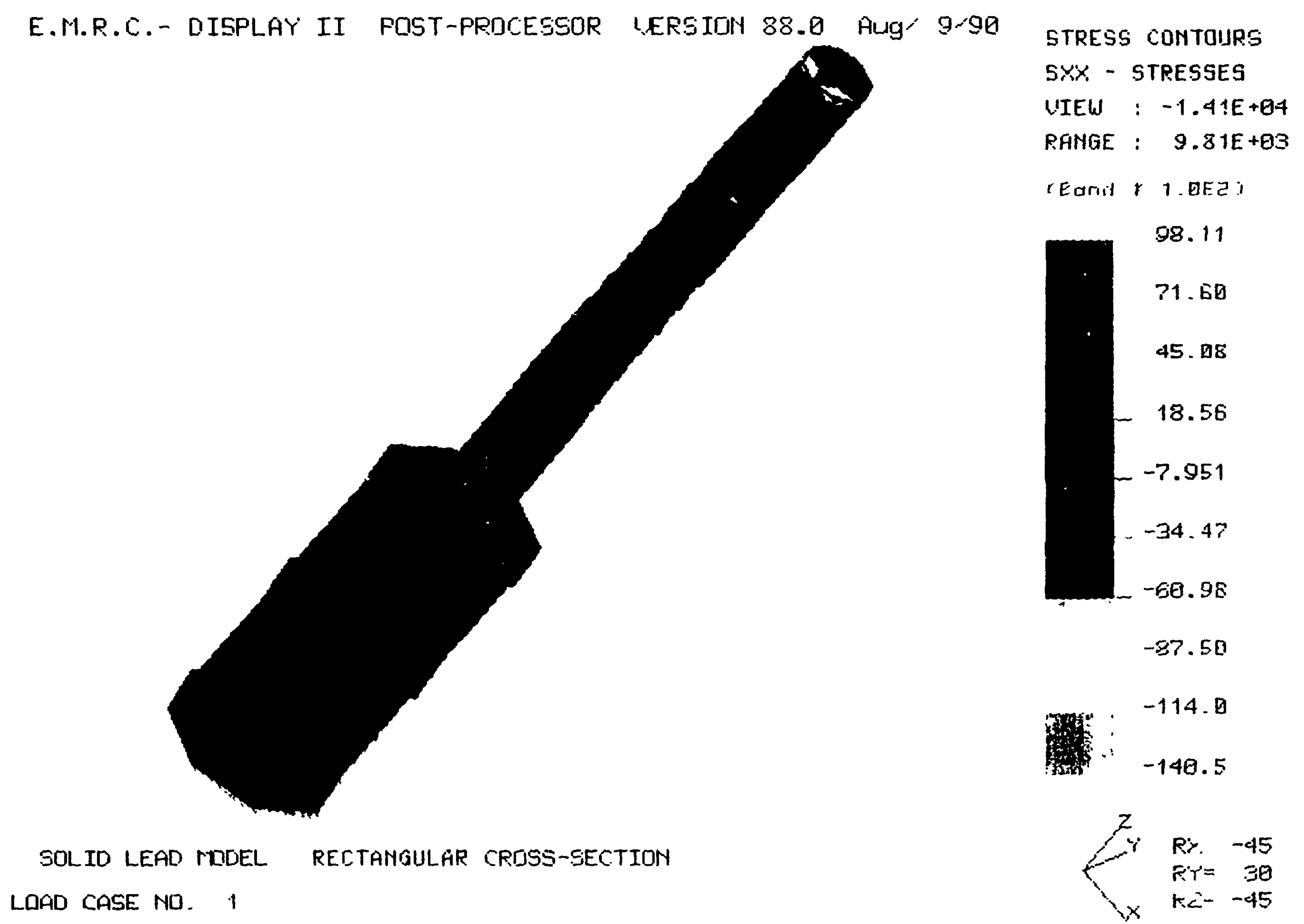
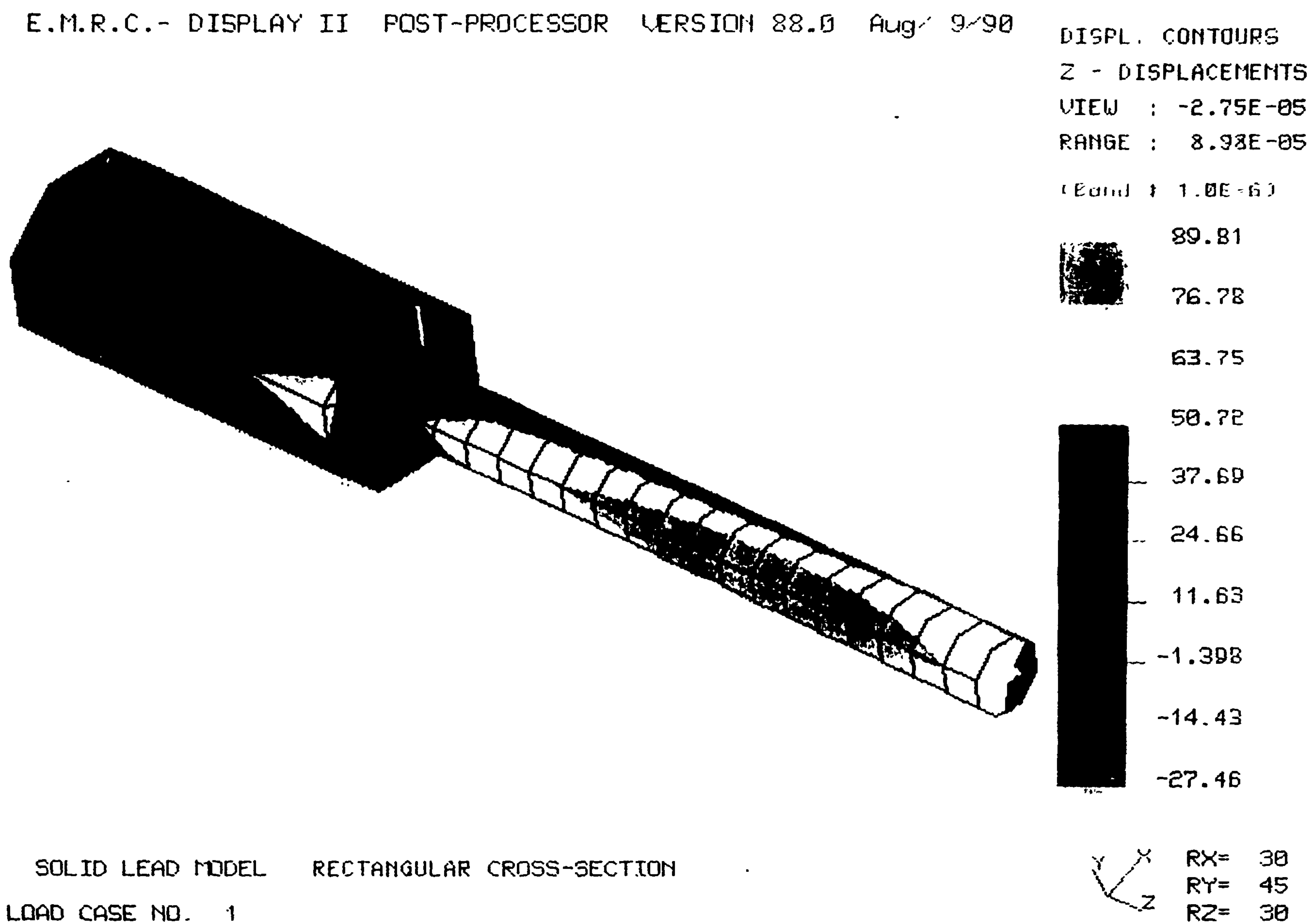

E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Aug/ 9/90
STRESS CONTOURS
SXX - STRESSES
VIEW : -1.41E+04
RANGE : 9.81E+03
(Band * 1.0E2)
98.11
71.60
45.08
18.56
-7.951
-34.47
-60.98
-87.50
-114.0
-140.5
Z
Y
X
RX= -45
RY= 30
RZ= -45
SOLID LEAD MODEL RECTANGULAR CROSS-SECTION
LOAD CASE NO. 1

Figure 8


E.M.R.C.- DISPLAY II POST-PROCESSOR VERSION 88.0 Aug/ 9/90
DISPL. CONTOURS
Z - DISPLACEMENTS
VIEW : -2.75E-05
RANGE : 8.98E-05
(Band : 1.0E-6)
89.81
76.78
63.75
50.72
37.69
24.66
11.63
-1.398
-14.43
-27.46
SOLID LEAD MODEL RECTANGULAR CROSS-SECTION
LOAD CASE NO. 1
Y
X
Z
RX= 30
RY= 45
RZ= 30
Figure 9

Effect of Mounting Type on PCB Life

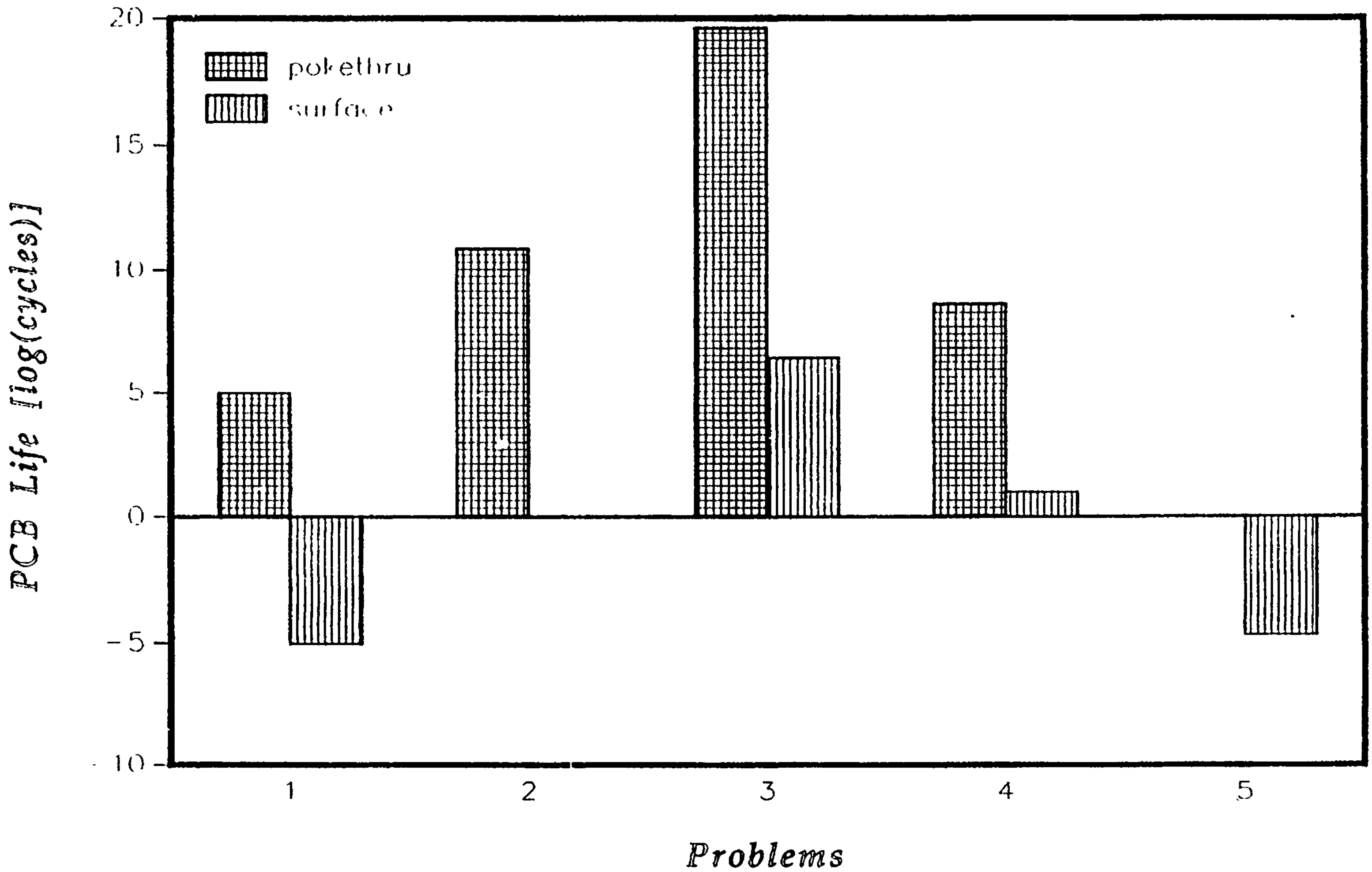


Figure 10

Effect of Mounting Type on PCB Life

		LIFE (log[cycles])	
Prob#	Component	Pokethru	Surface Mounted
1	DIP	4.9860	-5.0144
2	Hybrid	10.8740	------
3	Pin Array	19.5990	6.4018
4	Flat Pack	8.6207	0.98041
5	LCC	-----	-4.6801

Figure 10a

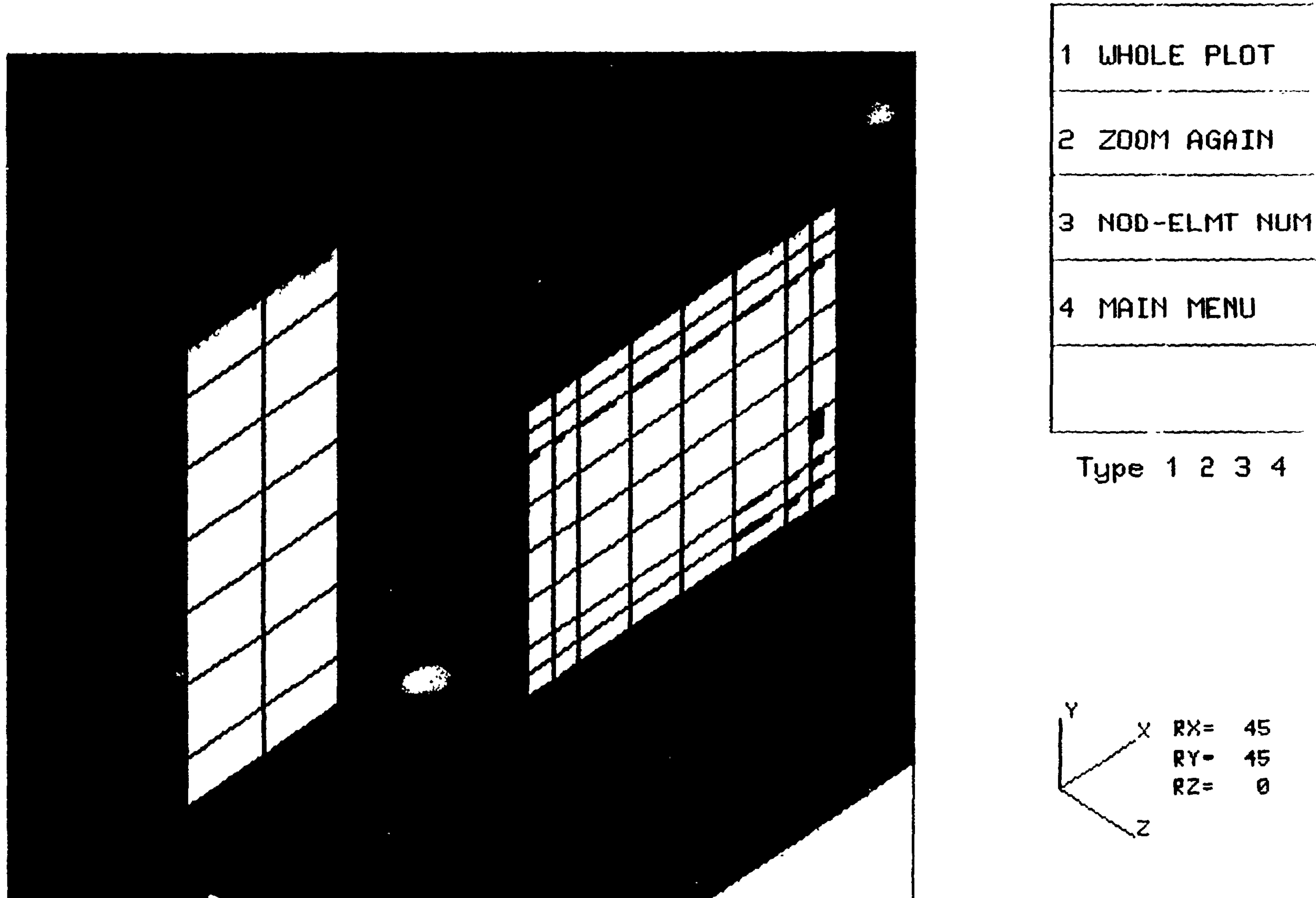

1 WHOLE PLOT
2 ZOOM AGAIN
3 NOD-ELMT NUM
4 MAIN MENU
Type 1 2 3 4
Y
X
Z
RX= 45
RY= 45
RZ= 0

Figure 11

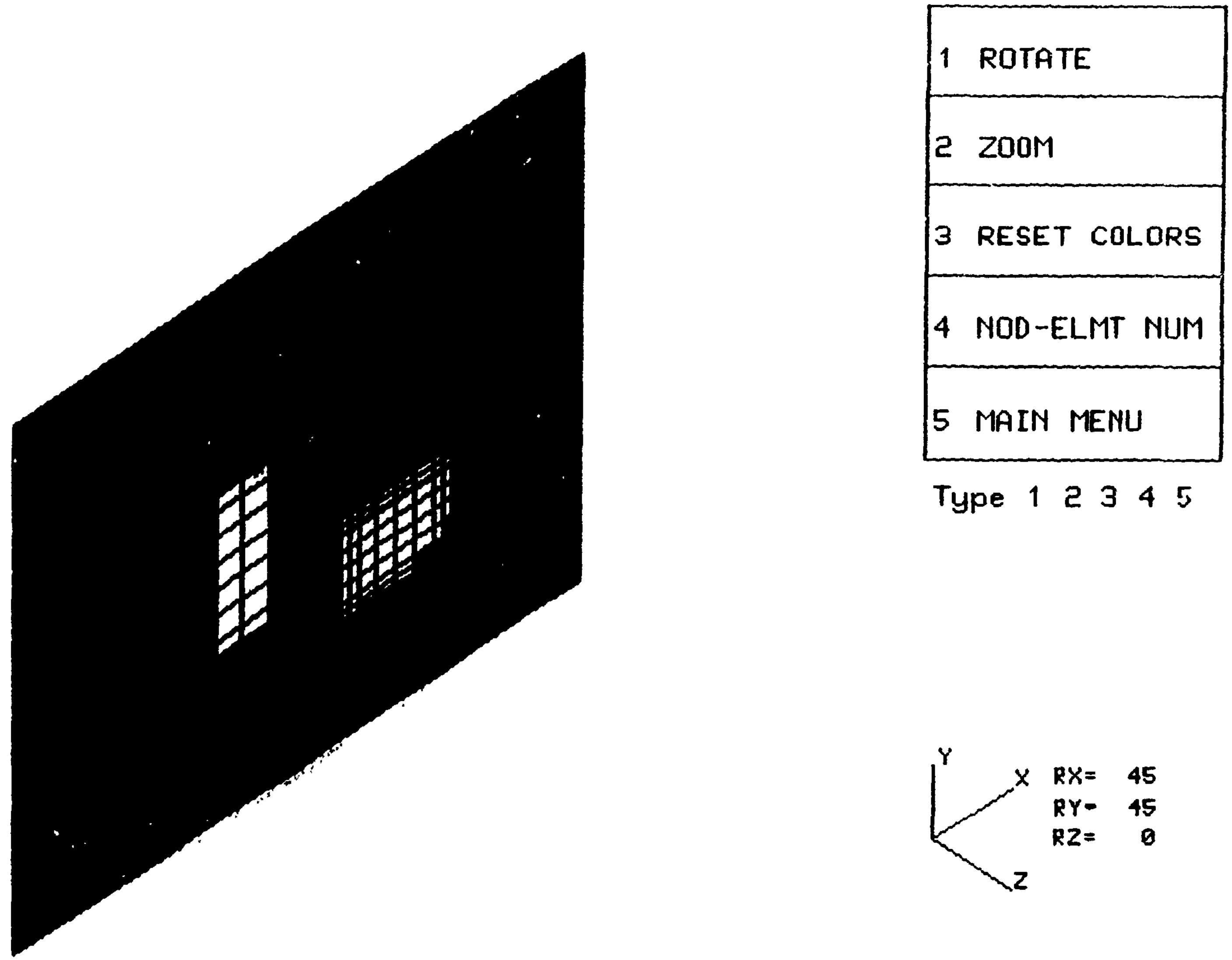

1 ROTATE
2 ZOOM
3 RESET COLORS
4 NOD-ELMT NUM
5 MAIN MENU
Type 1 2 3 4 5
Y
X
Z
RX= 45
RY= 45
RZ= 0

Figure 12

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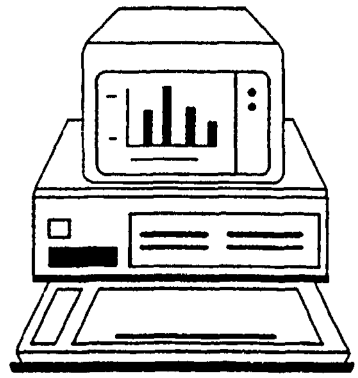
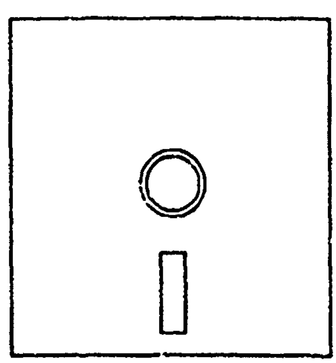
Soovre J. Guidelines for: the development of a computer-aided finite element vibration analysis program for PCB's mounted in LRU's. Burbank, California: Lockheed-California Company, April 30, 1986.



NAME: WENDY L. CHOATE
MENTOR: RICHARD SMITH
LAB: HIGH SPEED AERO PERFORMANCE
COMPUTER RESOURCES TEAM



The Computer Resource Team (CRT) is a group of unique individuals whose main job is to lend support to the Aeromechanics Division (FIM) on matters concerning computers. The CRT is responsible not only for the main computers (Prime and VAX) but also for the personnel terminals and the networks used within the Division and on the base. This responsibility not only covers maintenance, purchasing, and installation, but any question or problem concerning the computers, network, or printers, can almost always be answered by the CRT. Each member of the CRT has a area of specialty but individual members can answer almost any question or solve any problem.

This summer I worked with the CRT and my main job was to write a contingency plan for the division computer systems. A contingency plan is a plan that gives instructions to follow should a major "happenstance" occur. The main objective of the plan is to get the damaged area functioning in the quickest way, allowing the user to continue his work as much as possible. While writing this plan, I learned about many of the computers and software used by the division along with a little bit more about how the government operates. The computer I used the most was the Prime. I wrote a majority of the plan on the Prime, but I also performed other tasks on the Prime as well. Even though I used the Prime to write the plan, diagrams were needed and could not be done on the Prime. For this I used Publisher's Paintbrush on a Zenith Personal Computer. I knew and had used Paintbrush before coming to work, but I learned a great deal more about it while working on the contingency plan. Besides working with these two computers I also worked on the MicroVax (the other main computer) learning the computer language Ultrix, and learning about Silicon Graphics Workstations. The MicroVAX is used much like the Prime but is not as widely used. The Silicon Graphics Workstations are computers used to run simulations and draw graphics. All of these computers are hooked

up to the network so that if a person is one of these, he can hook up to another computer, (eg. If a person was on a terminal, he could easily have access to the Prime, the VAX. the SGI. or any other computer on the network used by the Division).

Due to the contents of the contingency plan only a few sections are on the following pages.

Acknowledgements

I cannot give enough thanks to the wonderful people I had the pleasure of working with this summer. I would like to thank Dick Smith, my mentor, Awilda Santana, Phyllis Smith, Charlie DeMarsh, Dave O'Reilly, and Mike Stringer who have been great teachers and even better friends. I would also like to thank Mike Alexander. Dave Johnson, and the rest of the Division. And I cannot forget the softball team the "Bootliquers". I had a great time and will never forget what I have learned.

TABLE OF CONTENTS

INTRODUCTION

This contingency plan was developed by the Computer Resources Team (CRT) of the Aeromechanics Division (FIM) of the Flight Dynamics Laboratory. It's purpose is to help insure that FIM engineers can continue functioning efficiently (albeit in a reduced mode) in the event of a "happenstance" to the FIM computer environment or any individual part of that environment. The goal is to keep FIM productivity high while simultaneously providing the engineers with a painless (as much as possible) method of continuing their work.

Realizing that FIM cannot afford complete backup of hardware and software systems that it utilizes, many sacrifices of convenience and computational power will have to be made.

This document describes the FIM computational environment at the time of its generation. FIM is fortunate in that it's computational environment is wide spread with elements in the north and south ends of Bldg. 450 and other elements spread widely within the Bldg. 24c complex. Thus the various pieces of the environment are highly unlikely to be at risk simultaneously.

Secondly, the document lists the envisioned possible disasters or damage causes which can have significant impact our computational capabilities and looks at the level of probability and level of risk involved for each of the areas in which equipment is used. Measures to minimize damage from the indicated potential problems are examined and defined.

Assuming that a "happenstance" has occurred, the document then goes into the appropriate mechanism to provide an intermediate computational environment. This is followed by a road map for placing the environment on a fully restored basis, possibly taking advantage of new technology, new contracts and reduced pricing.

Finally, the document defines the FIM software backup procedures for system and user software on all systems, including PCs. These backup procedures are deemed essential to any type of restoration of the computational environment, be it partial or complete.

A - ASSUMPTIONS

This section covers any support pledged to the division by outside organizations. At this time there is no support given by any other building or organization on the base except for the FIM operations in 24c which are part of the division. Building 24c can not lend great support because of its limited resources and space.

There are no current plans to obtain support of any of the other organizations or buildings.

C - STRATEGY

This section deals with what to immediately should a "happenstance" occur. This will not only cover personnel safety but also property safety as appropriate. The first priority in any disaster situation is to make sure that all personnel are in no danger.

There are many different kinds of disasters and even these disasters can come in different forms The following is a list of possible situations and what the immediate emergency response is.

CAUTION

Personal safety comes first. None of the procedures concerning the computers is to be followed if it in any way endangers personal safety. The first priority in any contingency plan is that of its personnel no matter what the damage to equipment and machines. Those can be replaced, a human life cannot.

1. Fire - There are many different ways a fire can be represented to you. The most dangerous is a fire in your immediate area. But whether it is in your area or in some other part of the building the course of action is primarily the same.

If you are at a terminal or in one of the computer rooms and there is a fire first turn of the terminal or emergency shutdown switch (only turn off the main computer if there is positive proof that there is a fire, as an unnecessary shutdown can cause more problems than a fire in another part of the building), pull the fire alarm or call the fire department at 911 and proceed to evacuate along the predetermined routes.

If you are at a terminal or in one of the computer rooms and you hear the fire alarm, first turn off your terminal or the emergency shutdown switch (only turn off the main computer if there is positive proof that there is a fire, as an unnecessary shutdown can cause more problems than a fire in another part of the building), then proceed to evacuate along the predetermined routes.

2. Water hazards - Water is a very dangerous substance when dealing with electrical equipment. In general, if water is found around or dripping on a user devices or one of the main computers, do not try to approach the machine and manually shut it off. Find a main power switch and turn the power off there or call a member of the CRT. If you find that there has been water damage to your terminal or the main computer and it is not on and there is no present danger call Charlie DeMarsh ext 51939, Dick Smith ext 55750, Dave O'Reilly ext 57207, or Phyllis Smith ext 51940.

3. Tornado or High Winds - Wright Patterson Air Force Base is situated along what is call tornado alley. So far there has not been much damage from a tornado but the possibilities are still high that one could occur. While at work you are not likely to hear of a tornado watch unless you have a radio, but should a tornado warning come into effect for the area around the base, base sirens will alert all base personnel of a tornado in the area. Should you hear this siren, turn off the user device you are at or the main computer, and immediately proceed to your predetermined tornado shelter area. If you are on an upper level, do not waste time, tornadoes are very unpredictable, so immediately go to the basement or lowest level of the building. If the building has no basement, find the most central, and smaller room on the lowest level away from any windows. Do not leave this area until you are notified that the warning has been lifted.

4. Power Outage - Power loss is not generally a dangerous situation, but steps need to be taken so that when the power returns, the surge of electricity does not damage the computers or their components. If the power goes out in your area, turn off your user device or if you are in one of the main computer rooms inform the CRT so they can shutdown the computer. If the power returns while you are still at the user device, turn it on and check it for any damage. Systems personnel will check out the Prime and the Vax systems and re-boot as required.

5. Air Conditioner Shutdown - Should the air conditioning shutdown in the Prime computer room, there is an automatic shut off switch that turns off the Prime at a preset elevated room temperature. A temperature cut off device for the VAX system in A010 is in the planning stages. If you enter one of these rooms and notice the air conditioner is not operational notify a member of the Computer Resource Team.

6. Computer Virus - Should you come across a computer virus, first isolate the system, do not try to analyze the virus, and then call CRT personnel Awilda Santana ext 51939 or Dick Smith ext 55750.

7. Computer Hacker - If you come across a network hacker on your system or have found traces of one first call the CRT and they will call DCA DNN Defense Communications systems 1-800-235-3155 or for 24 hour service call MiLnet Trouble Desk (A/V) at 231-1713 or 1-(800)-415-7413.

8. Bomb Threat - A bomb threat is not a regular occurrence but is not unheard of within in FIM. There are a strict set of guidelines to be followed should a bomb or bomb threat be encountered. These guidelines are listed in every room of every building on base. The following is a list of the guidelines:

If you receive threat from unidentified source

1. Ask for bomb location and detonation time.
2. Listen for voice enflections, tonal qualities and background noises.
3. After the caller hangs up, you may also hang up; calls are **NOT** traceable.
4. Immediately notify:
   Security Police, ext 71100
   Command Post, ext 76314
5. Notify your building manager: Bldg 450, D/P 54796.
6. Advise your supervisor.
7. Secure classified material.
8. Visually identify any strange objects or packages in office/area.
9. **If nothing found, reverse card on door and post outside entrance to office/area.**
10. If any found --**DON'T TOUCH**-- call security police, ext 76841 and re-notify bldg. manager.
11. Open all windows and unplug all electrical appliances.
12. Collect personal belongings.
13. If directed -- evacuate building to point directed and take cover; otherwise, resume duties.

If threat notification received through **OFFICIAL SOURCE**
Accomplish items 6 - 13 above, as applicable.

D - RECORD OF CHANGES

This section is provided to record any changes made in the contingency plan. All changes should be recorded on this paper with the appropiate information, name, section where change is being made, date, and a brief summary of the change.

NAME	SECTION	DATE	SUMMARY OF CHANGE

SECTION II - PREPARATORY ACTIONS

This section gives a description of all the resources used by the FIM division and any precautionary steps already taken. The following is a list of the resources in both building 450 and 24c.

A. Personnel
B. System Back-ups
C. Software
   1. Prime 6350 and 2350
   2. MicroVAX
   3. SGI Workstations
   4. Zenith Computers
D. Hardware
   1. Prime 6350 and 2350
   2. MicroVAX
   3. SGI Workstations
E. Networking/Communications
   1. In Building
   2. Outside Building
F. Documentation

A - PERSONNEL

The AeroMechanics Division Diaster Contingency Action Team will be comprised of two type of members. The primary members will be made up of the FIM Computer Resources Team (CRT) members. They will be backed up by knowledgable users and management personnel as deemed necessary. Appendix A details the personnel and service organizations that must be notified in the event of a disaster or emergency affecting the FIM Computational Environment.

The primary members of the Diaster Contingency Action Team (DCAT) are:

Name	Office Symbol/Location	Home Phone #	Work Phone #
Dick Smith	WRDC/FIMG/Bldg 450/Rm A02	434-1750	55750
Charles Demarsh	WRDC/FIMG/Bldg 450/Rm A02	233-2305	51939
Awilda Santana	WRDC/FIMG/Bldg 450/Rm A02	233-7108	51939
Dave O'Reilly	WRDC/FIMG/Bldg 450/Rm C11	323-6002	57207
Phyllis Smith	WRDC/FIMG/Bldg 450/Rm C130	326-5769	51940

The secondary & backup members of the Diaster Contingency Action Team are:

Name	Office Symbol/Location	Home Phone #	Work Phone #
Jim Hayes	WRDC/FIMG/Bldg 450/Rm A207	864-2016	53439
Steve Scherr	WRDC/FIMM/Bldg 450/Rm A123	438-9137	52455
Hank Baust	WRDC/FIMN/Bldg 24c/Rm 001	429-0360	52493
Ed Collins	WRDC/FIMT/Bldg 450/Rm A114	429-5120	54077

Management representatives of the Diaster Contingency Action Team are:

Name	Office Symbol/Location	Home Phone #	Work Phone #
Al Draper	WRDC/FIM/Bldg 450/Rm A126	426-2125	56156
Dave Selegan	WRDC/FIM/Bldg 450/Rm A126	434-5054	56795
Val Dahlem	WRDC/FIMG/Bldg 450/Rm A225	233-0455	55806
Dennis Sedlock	WRDC/FIMM/Bldg 450/Rm A106		54579
Tom Weeks	WRDC/FIMN/Bldg 24c/Rm 101	426-3533	52139
Lt Col Gotcher	WRDC/FIMT/Bldg 24c/Rm A114	878-0330	54077
Lt Col Sanchez	WRDC/FIMX/Bldg 450/Rm E128	429-9984	56795

B - SYSTEM BACK-UPS

The following system file backup procedures are in effect for the FIM computational systems. These are broken out by system.

A. Prime 6350 system

All Prime 6350 disk storage subsystem files are backed up weekly on a schedule as shown in the Prime Systems Book. Up to date copies of this book are kept in the Prime Computer Systems operator office area (C130), the System Managers office (C011) and the CRT office in Room A04.

Tape storage is maintained in the room adjacent to the Prime Computer room, C130, with another copy stored in room A010 of Bldg. 450. The separation of the storage rooms is approximately 1000 to 1200 feet, in different wings of Bldg. 450. Back up tapes are created daily with a rotating sequence of disk storage partitions. As the tapes are created in the Prime 6350 computer room, they are then exchanged for like tapes in room A010 which then will be used for the following week backup of the same partitions. There are two complete sets of tapes (approximately 20 tapes are required for each full backup) with each set being color coded to avoid accidental overwrite. This provides each file with two week protection and recovery potential. Many instances of recovery of user files lost, due to user error or disk drive failure, have demonstrated the viability and efficiency of the above disk subsystem backup and storage procedures.

Plans: An 8mm backup system for the Prime 6350 has been procured. Such a backup system will allow large portions of the disk subsystems to be backed up on a more frequent basis while minimizing the volume of tapes which have to be stored. Currently, the 9-track system used, stores approximately 90 Megabytes per 9-track tape. The 8mm system will store approximately 1.2 Gigabytes per cartridge tape. Installation of the 8mm back-up system will be Sept. 13, 1990.

B. Prime 2350 System

The Prime 2350 system is located in the Bldg. 24c complex. Current interconnection between the 2350 and the 6350 is via an asynchronous fiber optic link. Thus presently disk subsystem backup is controlled by the users in FIMN, Bldg. 24c. These backups are done daily using the system cartridge tape drive. Storage of these tapes is presently nearby.

Plans: Efforts are underway to improve connectivity between the 2350 and the 6350 via Ethernet and the Area B fiber optic cable system. Ethernet hardware and software has been procured for the 2350 and similar hardware and software is on the 6350 system. When this connection is completed, it will be possible to backup the 2350 by the system manager in Bldg. 450 with storage of the backups included with the 6350 backup storage schema. Planned completion of this effort is Fall, CY90.

C. DEC systems

FIM has two M2 microVAXs in building 450. Here, each system is backed up weekly utilizing the 9-track tape drive and the cartridge tape system. For the M2 system in room A010, two copies of these tapes are created weekly with one stored in room A010 and one in room C130 of Bldg. 450. Back-up tapes for the Hypersonic Wind Tunnel (HWT) VAX will be stored in either Bldg 24c or in room A010 of Bldg 450.

Plans: There are no current plans for modification to the backup procedures of these systems.

D. Silicon Graphics Workstations (SGI)

FIM has 15 SGI's, 14 in building 450 and one in 24c. There presently is no automatic back-up system for any of the SGI's. Eight mm cartridge tape systems have been procured and installed on two SGI systems on each floor of Bldg 450. Through use of the Network File Service (NFS) on each SGI workstation, a schema is being developed wherein all SGI systems will be backed-up on the four 8mm cartridge tapes on a regular basis. Tapes are stored jointly within the immediate SGI area and also in the Prime computer room of 'C-Wing'.

Plans: There are no plans to modify the SGI backup procedures.

E. Zenith Workstations

FIM has 26 Zenith computer systems (18 Z-248 and 8 Z-100) in building 450. Currently there are no central back-up pocedures for any information stored on the microcomputer hard disk. All back-ups must be done by the user onto a floppy disk or into one of the main computers. Users are encouraged to provide the CRT with duplicate copies of their back-up disks. All system software disks are secured remotely from the microcomputer areas.

Plans: Equipment has been ordered to Network the microcomputers, the goal is to allow the micros to be backed-up utilizing the SGI workstation 8mm cartridge tape systems.

E - COMMUNICATIONS

This section gives a detailed description of the communt cations within the building and between building 450 and 24c. The networ} between 450 and 24c is not yet complete. so this whole plan is based on that it is not yet up and running but there is a complete description of it in this section.

IN THE BUILDING COMMUNICATIONS

OUTSIDE COMMUNICATIONS

F - DOCUMENTATION

This section covers the documentation used by the FIM personnel. There is no real threat of losing all of the documentation in the building at once. If that should happen, documentation can be readily replaced from vendors and other base organizations. There are multiple sets of documentation for every system in the division in different locations within the building.

If you are unable to locate a certain document call CRT personnel at 51939, 55750, or 57207.

SECTION III - EMERGENCY ACTION PLAN

Building 450

1. Loss of Primary Computers
   a. Loss of Prime
   b. Loss of either one of the two VAX M2 workstations
   c. Loss of both VAX M2 workstations
3. Loss of any number of Silicon Graphics Workstations
4. Loss of Back-up data.
   a. Loss of one set
   b. Loss of both sets
5. Loss of communications
   a. Loss of in building communications
   b. Loss of out of building communications (specifically with building 676)
6. Loss of systems that are cleared for classified use
7. Loss of personnel
8. Loss of microcomputers
9. Loss of some or all resources in building 450

Building 24c

1. Loss of Primary Computers
   a. Loss of any of the three MicroVAX
   b. Loss of Prime 2350
2. Loss of microcomputers
3. Loss of communications
   a. In the building
   b. Out of the building (specifically with building 450)
4. Loss of personnel
5. Loss of Silicon Graphics Workstations
6. Loss of some or all resources in building 24c

SECTION III - EMERGENCY RESPONSE

I. The most important part of this Division is its personnel. A chain of command is established ahead of time in the event the personnel are lost due to the 'happenstance'. Personnel are cross-trained and there is a pyramidal alert system that will be utilized to notify the appropriate personnel.

II. The Prime 6350 computer is one of the major computers used by this Division. There are two Prime computers (one in building 450 and one in 24c) being used by FIM. Should anything happen to one or any combination of these computers, steps need to be taken so that the work done by the division is not hampered.

A. Should the Prime computer in building 450 (the Prime 6350) be damaged or destroyed, the other operational Prime computer can back-up a limited amount of work. Considerable work can be handled by the 6350 than by the 2350. The MICROVAX can also be used to handle some of the extra work. An unused Prime 750 can be brought back on line in short order to help absorb the work load. Similarly, WRDC/TX has an operational Prime 750 in 'B-Wing'. A working relationship has been established with TX which would allow FIM users access to the TX Prime system.

B. Should the Prime in building 24c (the Prime 2350) and the Prime in 450 both be damaged or destroyed the a limited amount of the work can be transfered to the MICROVAX's which are located in both buildings. The FDLENGVAX, although at near capacity utilization, can also be used to help carry the workload. Once the network is completed it will be possible to transfer work readily from building 450 to building 24c and visa versa.

III. The MICROVAX is another main computer used by the division. At present there are three MICROVAX computers in building 24c (three M2) and two in building 450 (two M2). Should any one or combination of these computers be damaged or destroyed the Prime computers and the remaining VAXs (if any) can compensate the work to a limited degree. **NOTE:** Four are VMS, one Ultrix.

IV. Should both the Prime and the VAX(s) in one building be inoperable the other building can compensate a limited amount of the work load. It will be easier to transfer the work once the communications network is completed between buildings on the base.

V. Data tapes are currently being used to back-up both the Bldg 450 Prime and VAX computers. Two set of tapes are made, rotating every week, to give two weeks worth of back-up material. These tapes are kept at both ends of the building . Should one set be destroyed the other set can be used to restore the system to operational status. Should both sets of tapes be lost there is no way to restore the lost data unless is was also stored by the user personnel on an external system.

VI. Communications

VII. One of the computer rooms in Building 450 is also a classified work area. In this area are two SGI workstations, a Z-150, a Z-200, and two terminals, all of which are approved to process classified information. Should anything happen to any one or any combination of these systems the course of action is to proceed to another area having approval to process classified information or to wait for replacements and clearance for the replacements to process classified information.

VIII. Within in this division there are 26 microcomputers. Should any number of these be damaged or destroyed the primary course of action is to transfer use to another microcomputer or wait until the damaged one is operable again.

IX. Microcomputers and terminals are used to access FIM's primary computers, and other external computer systems. Should any of these be rendered inoperable the primary response is to transfer use to another terminal, until the damaged unit is replaced. Should over 50% of the units be inoperable a system will be established to organize space and time on the remaining units.

X. Like the microcomputers and terminals, loss of a few of the SGI workstations can be compensated for. Should a large number of these be inoperable a system will be established to organize space and time on the remaining SGI's so that everyone has an opportunity to continue their work.

XI. If a virus has been found on a system, the virus must be removed and damaged files restored from the backup tapes. Before the virus is removed, the system must be isolated, no logins allowed, and notification given to WRDC/FIOC and ASD/SC thru CRT personnel.

A. If a hacker has been in a system, all system and user passwords will be changed. Do not use anything that would be easy to discover like names or initials and change the passwords frequently. Also check the files to ensure that nothing has been tampered with by the hacker.

B. To prevent viruses from getting into the systems, refrain from using shareware, public domain, or friendly programs and software.

XII. The most damaging happenstance that can occure to this division is the partial or total destruction of one or both buildings 450 and/or 24c. Should one of the buildings be destroyed the only option is to transfer what can be transfered to other systems for temporary and limited use. Should both buildings be destroyed arrangements need to be made with other organizations for temporary and limited use.

SECTION IV - DAY TO DAY OPERATIONS

This section covers what to do in a situation that is not vital or dangerous to the Division . Most situations should be reported to the Computer Resource Team for corrective action or maintenance. The following is a list of situations and what to do.

1. If there is damage of some kind to a user device call Charlie DeMarsh ext 51939 or another member of the Computer Resource Team.

2. If there is a problem or questions concerning the system being used (Prime, VAX, etc.) call either Dave O'Reilly ext 57207 (Prime), Awilda Santana ext 51939 (VAX), or Dick Smith ext 55750.

3. For any other problems that are not vital to the operational status of the divisions computer resources fill out a trouble report form and submit it to Phyllis Smith (Prime Computer Room, Rm C130) where it will be logged in and assigned for response.

COMPUTER RESOURCE TEAM

NAME	Work Phone #	Areas of Action
Dick Smith	55750 or 51939	
Charles DeMarsh	51939 or 55750	User general hardware and network problems
Awilda Santana	51939 or 55750	MicroVAX hardware and software, microcomputer software
Dave O'Reilly	57207 or 51940	Prime systems, Laser printers, supplies
Phyllis Smith	51940 or 57207	Prime 6350 operations

SECTION V - SUGGESTIONS

This section list suggestions to supplement the contingency plan. Most of the suggestions deal with precautionary methods that are not presently in place.

1. A third, off site, facility to store back-up tapes. Should both tape storage places be destroyed there are no other back-up tapes. Even though the possibility of both rooms being destroyed is very remote, there is still the possibility. And should that happen, this division will be significantly shutdown except for personal back-up media or data existing on external computer systems.

A possible solution is that back-up tapes be switched between buildings 450 and 24c (the tapes for 450 be stored in 24c and the tapes for 24c be stored in 450). It does not have to be every weeks tapes, but a monthly back-up could be done and stored in the other building.

2. There is not a complete sprinkler system for building 450. A-wing does not have sprinklers throughout the wing. This posses a significant threat should a fire start in this wing. Should a fire start in one A-wing room, there are limited automatic alarms to warn personnel.

The solution here is to install a complete and up to date fire system for building 450. This installation would include fire detectors, fire alarms, sprinklers, fire extinguishers, and a thorough inspection of all fire equipment in the building in addition to the inspection already done once a year. This inspection should cover every aspect of the system and should be extremely thorough. A recent fire in B-wing showed that there are also no sprinklers in that wing. If someone had not been in the building to notice the fire it could have easily spread to a larger portion of the building.

3. The Prime computer room is equipped with a device that shuts off power to the room should the temperature in the room rise above a set amount. The Vax computer room is not equipped with this device. The Vax computer room is also used as a classified work place and is very important to the Division. The Vax computer room needs to be fitted with a similiar system to prevent damage should the air conditioner fail. Work towards this end is being accomplished by FIMN.

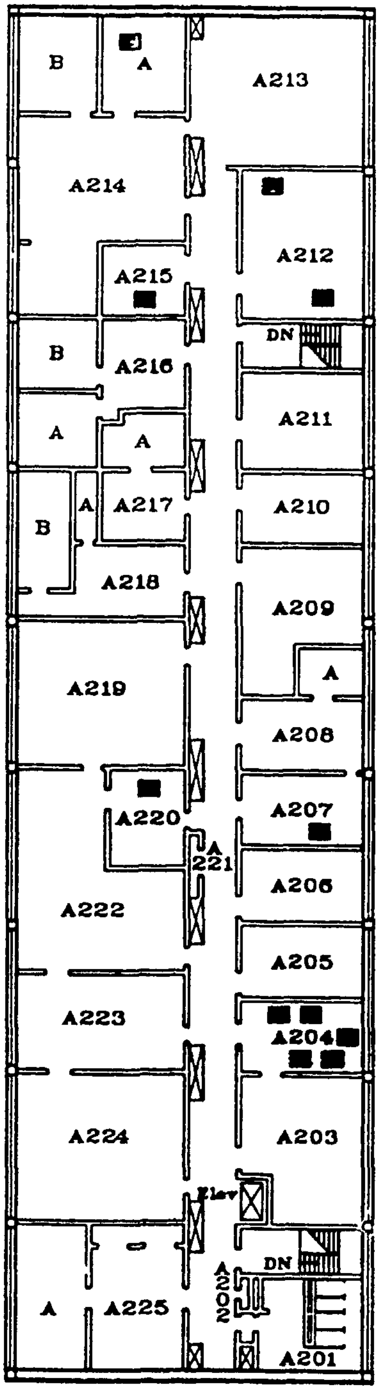
4. Water damage is the biggest threat to the FIM Division. A fire alone may not do very much damage but the water required to extinguish the fire could destroy many of the computers not even touched by the fire. However, a recent fire in a Propulsion Labratory computer workstation in B-Wing of Bldg 450 showed the fire department to be extremely effective in knocking down the fire and limiting the water damage.

One solution here would be to purchase plastic covers for all of the systems in the division. These covers would be placed on the computers at the end of every work day. Frequently disasters will occur when nobody is in the office. Such covers will also protect the computers from other types of damage such as water leaks from the ceiling air handlers, etc. No covers would be purchased for the VAX, the Prime, or the SGI's. These computers generate a significant amount of heat. Such covers would limit the air circulation around the computers thus increasing the temperature and igniting a fire within the computer or igniting the covers.

SECTION VI - TESTING AND MAINTENANCE

This section deals with the testing and maintenance of the plan. Because of the problems that would arise from implementing this plan when it is not necessary, not much testing can be done on the primary computer systems. Periodic fire drills, power outages, lighting strikes, and power surges provide ample opportunity to test portions of the plan under real conditions. but they normally do not involve the shutdown of all the computers systems.

At this time the network between building 450 and 24c is not complete, but when it is tests will be run to see how easily back-up data can be transfered between buildings and if a partial work load from one building can be transfered to the other. It is not necessary for it to be a periodic test, but will be run once when the network link has been completed.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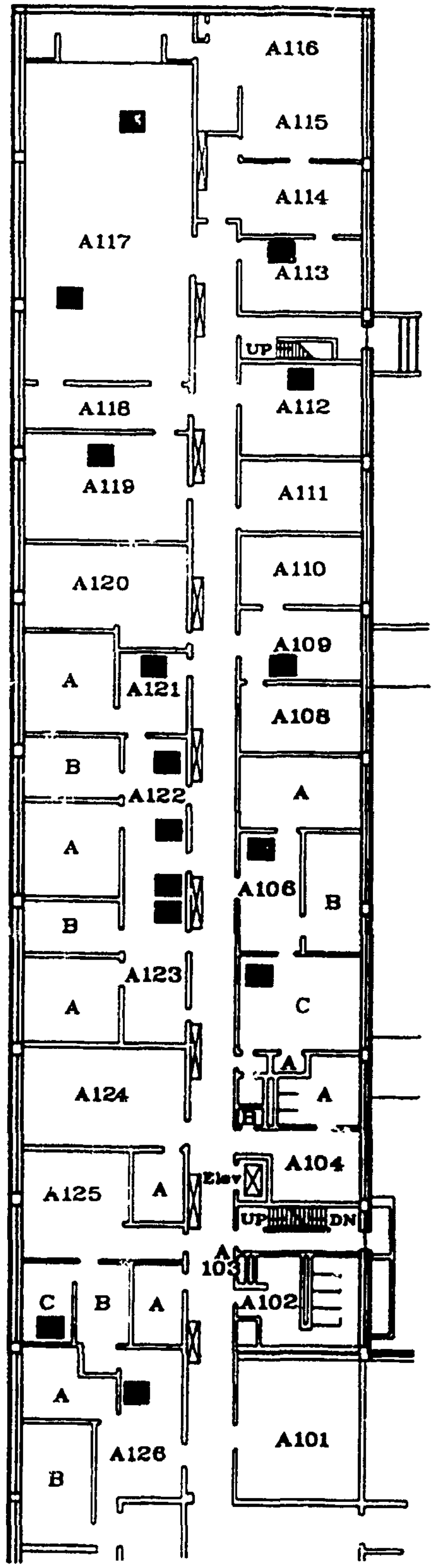
"A" Wing

■ = SGI

■ = PC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"A" Wing

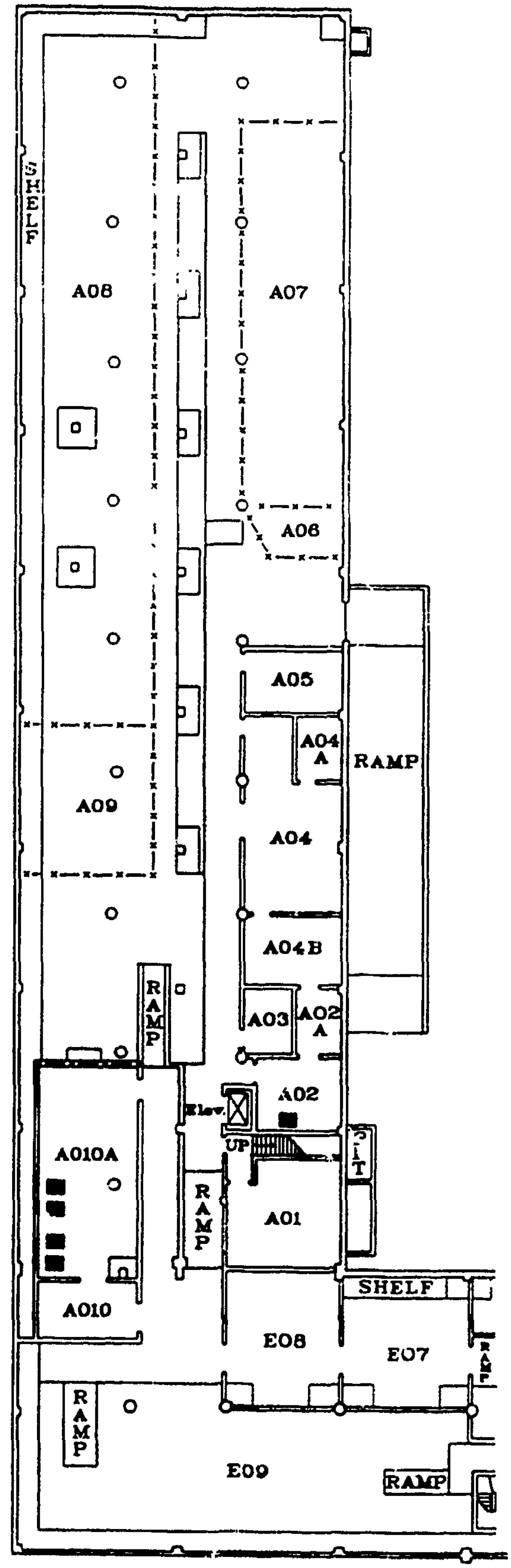
■ = SGI

■ = PC

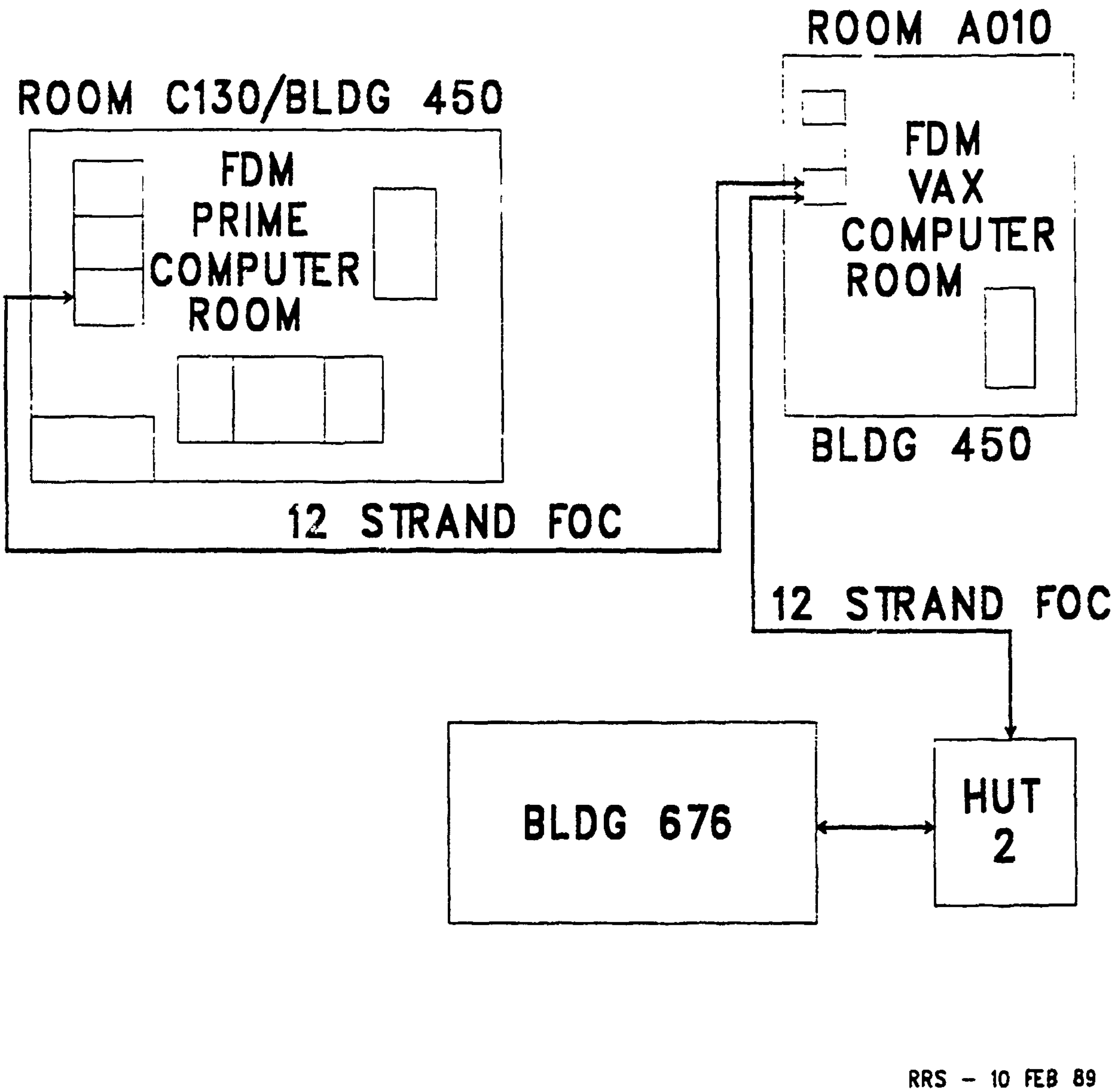
"A" Wing

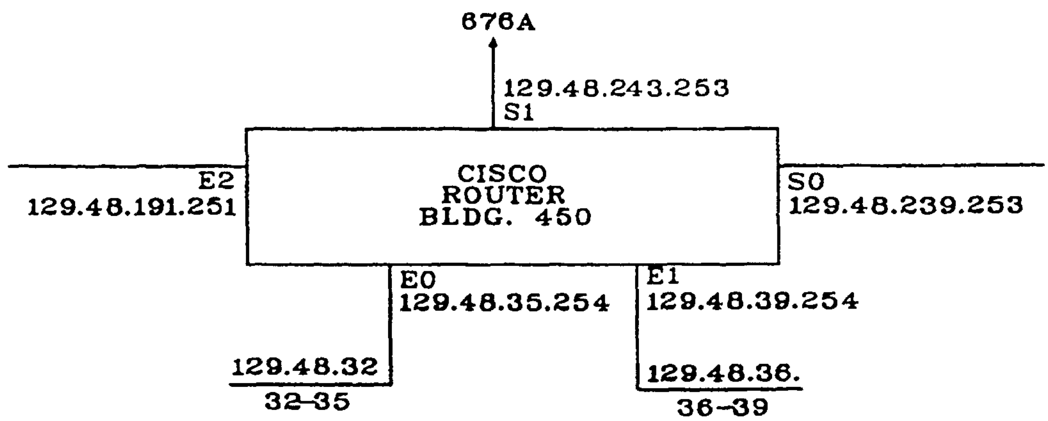
□ = PC's

■ = SGI

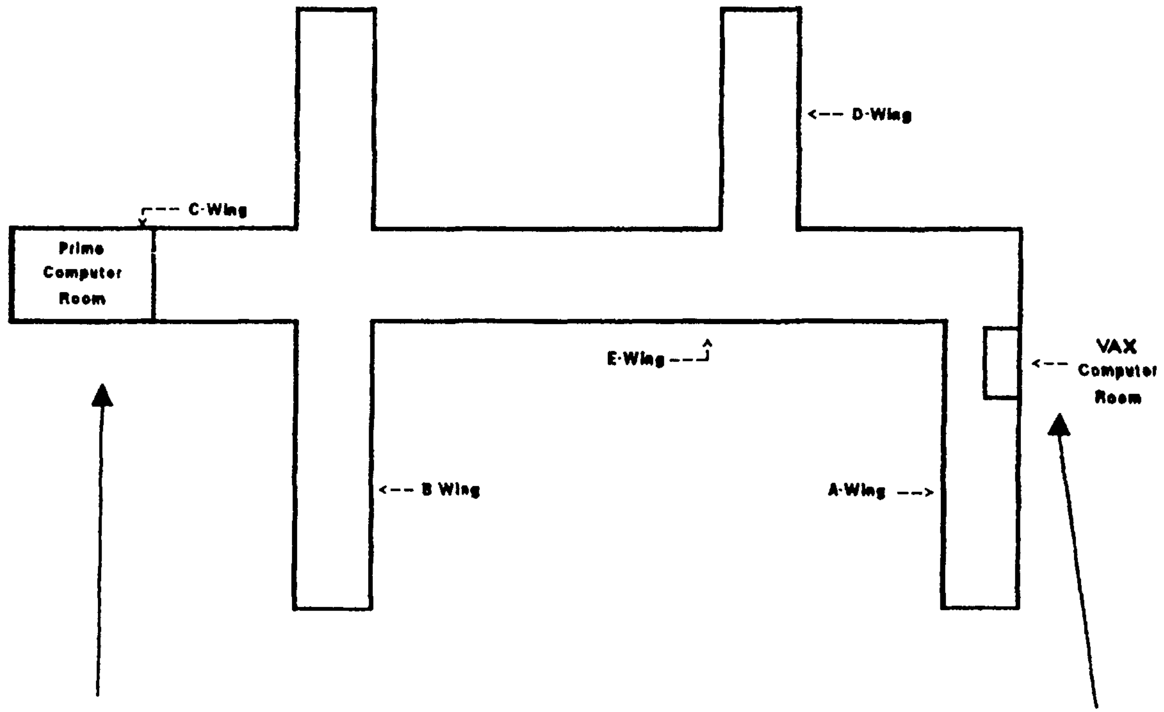


FIM FIBER OPTIC CABLE LAYOUT





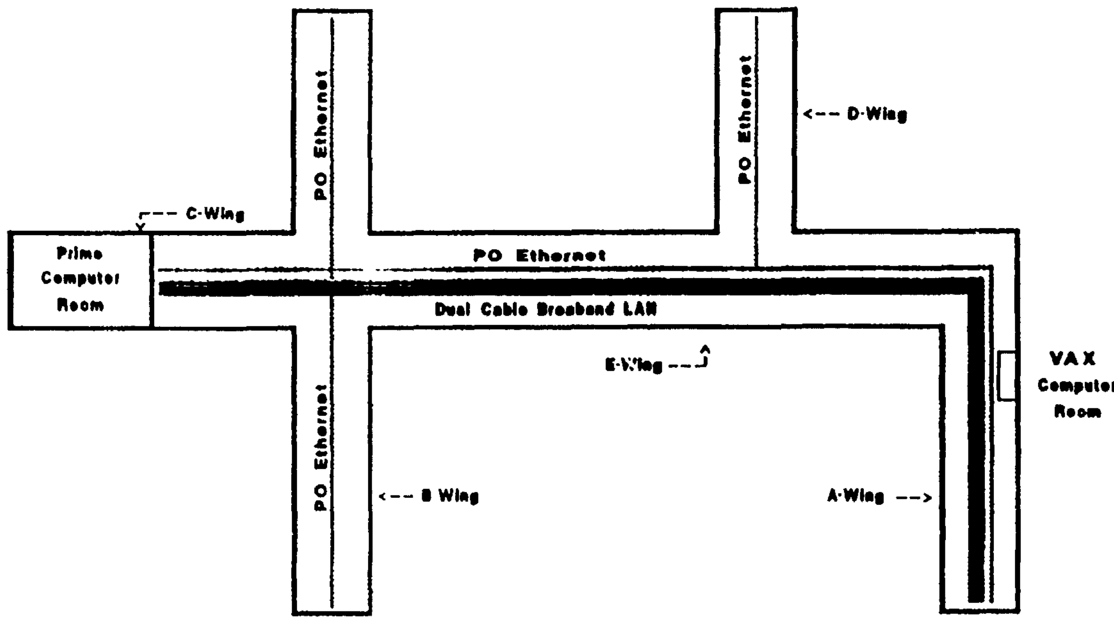
S – SERIAL (1.54 MBIT)
E – ETHERNET (10 MBIT)



BACKUP STORAGE SITES FOR

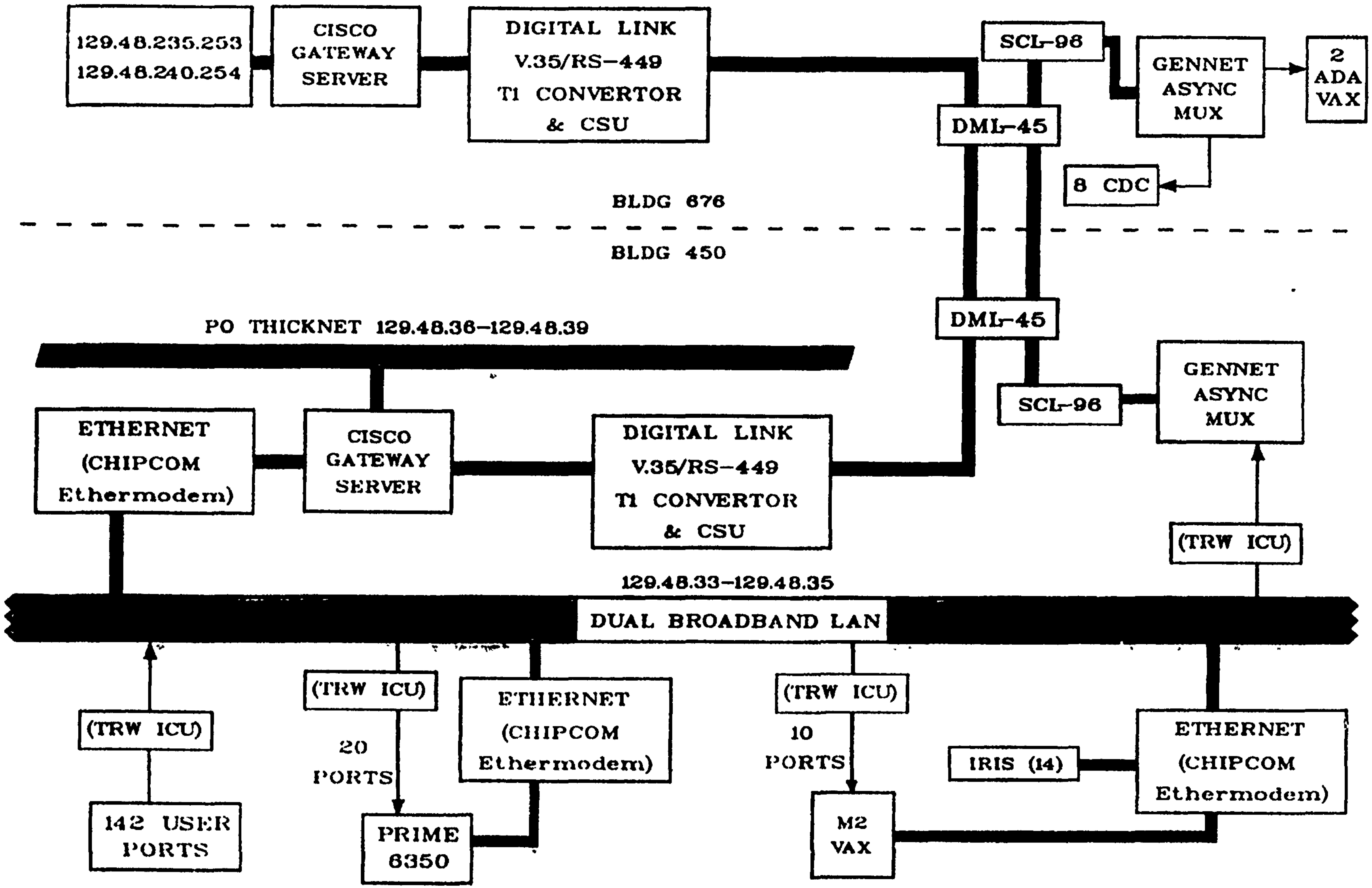
BLDG 450

BUILDING 450 BROADBAND & ETHERNET LAYOUT



- FIM BROADBAND UTILIZES TRW ICU INTERFACES
- FIM ETHERNET UTILIZES BROADBAND VIA CHIPCOM ETHERMODEMS
- PO ETHERNET IS THICKWIRE
- TX ETHERNET IS THICKWIRE (B-WING & PART E-WING)
    - NO CURRENT CONNECTIVITY OUTSIDE TX ORGNIZATION

8 AUG 1990
WIC



Bldg 450 to Bldg 676 Ethernet & Asynchronous terminal Connectivity

Andrea Dean

Final Report Number 78

No Report Submitted

Leading Edge Heat Exchanger

Rachael R. Lyon

Mr. William McHugh

Flight Dynamics Laboratory

13 August 1990

I. Introduction

In the summer program I learned many new concepts and learned the operation of writing code for one of the Leading Edge Heat Exchanger circuit cards. Besides writing code, I had hands-on experience and received a chance to learn about the many interesting areas of electronic engineering.

II. Acknowledgements

I would like to thank everyone that made my summer enjoyable and advised me in many areas of the career field I may eventually be exposed to. Mr. McHugh, my mentor, taught me many valuable lessons in the area of electronic engineering and the reality of dealing with challenging situations under any circumstance. He told me to recognize the similiarities and then the differences. He exposed me to different enviroments within the world of engineering and introduced me to various people in different occupations. Mr. McHugh gave me a chance to talk to those people and find out what they do in their position. I enjoyed working with Mr. McHugh very much. Through the Air Force and U.E.S., he gave me opportunities I have never had and also made learning enjoyable. I have an overflow of gratitude for all he has done.

I would also like to thank all the engineers who took time to talk to me about their career and the project they are working on. They gave me advice that I know will help in

the future.

In other respects, I thank the others I worked with and met during the summer program. I appreciate the advice and making sure I enjoyed myself.

I am also grateful to those who chose me to be in the summer program. I learned more than I thought I would about electronics and many other matters. I enjoyed everyone I worked with while working with Mr. McHugh. I had fun learning many concepts and operations because I was interested in what was being taught and because of the way it was presented to me.

Thanks again to everyone I met and became good friends with. I'll never forget how enjoyable you made my summer or the advice you gave me.

III. General Description

While working in the structures branch of the Flight Dynamics Laboratory this summer, Mr. McHugh and I generated a computer program which will be used to control a circuit card for the Leading Edge Heat Exchanger project. I learned how to operate in OS-9 and programmed in the Basic09 and assembly languages. Doing this I learned the method of writing code for a specific task. The code we wrote is used to set the variables in the Basic program to reflect the state of the panel switches by monitoring function selection cards. If the state of the panel switches are false, the

program sees the switches as not active and if the state of the switches are true, the computer sees this as active. In either case, if there is a change in the panel switch, the program will set the change flag. Whether the switches respond true or false, the computer shows all the switches and their state. This program also informs the operator if any switch in the entire program has changed by displaying the state of the switch on a CRT display monitor. The operator decides whether the changes are correct or not, depending on on the program condition.

IV. Detailed Description

In the first two weeks of the program, Mr. McHugh introduced me to the project I would be working on and described the process of designing a system. He showed me diagrams of the circuit cards and explained how they work. He also showed me his notes that would eventually work into the code we would be designing. Mr. McHugh told me I would be working on learning how to use the Basic09 and the OS-9 operating system's editing functions and learn how to work in assembly language.

For the next few weeks I studied sections out of the manuals on the Basic09 and OS-9 editing codes. I read them, took notes on what I read, and got on the computer and typed in some simple code to use the editing commands I learned.

While I was learning these new editing skills, Mr. McHugh taught me different things about electricity. He also let me

practice my skills by typing in a copy of a program he used on a diverse project. While I typed in the code, he explained what the program basically does.

When I felt proficient with the new commands, we started writing a psuedo code to base our actual code structure on. In the beginning of the code, there is a description of the program's process. Throughout the program there is also comments in each command line to let anyone who reads the program understand what each command line executes.

About the sixth week, We wrote a subroutine for one of the ciruit cards called "Panel_Ck". The code is in assembly language and interacts with Basic09, getting and passing information. The program is used to collect switch information from the switch panel. It sets the variables in the Basic program to reflect the state of the panel switches and passes the address of the pia, which controls the function selection cards. It assumes the pia is configured for Port A as input and Port B as output. The program responds true if a change has been made within the period of time of the previous run of the program. If there has been no change, it will respond false. Then it shows the state of the individual switches in the same manner with the true and false statements.

It only took a day to type in the code after it was designed. After we programmed in the code, we checked the subroutine and edited the mistakes that were made. After

editing the program, it took a few days to debug the entire program. We discovered errors and corrected them. Some of the errors we made were typing mistakes and others were lines where there were mistakes with address modes or instructions. We debugged the program so, that if a problem occurs within the program, we would be able to locate the area easily.

The code is going to be based on a booleen algebra code Mr. McHugh has yet to write. Since the apprenticeship program was limited to an eight week period, we only accomplished writing one ciruit card's subroutine. For the reason that the Leading Edge Heat Exchanger program is in the beginning of the fabrication process, we could not actually run "Panel_Ck" on a test.

V. Other Areas of Interest

Mr. McHugh showed me different areas of electronic engineering than just writing a subroutine to control a circuit card for the Leading Edge Heat Exchanger project. I learned about some electronic measuring devices, the oscilloscope and the digital multimeter, and I got a chance to measure voltage, resistance, and current using these instruments. I also had "hand-on-time" soldering some resistors, in a circuit, to explain Ohm's Law. At the same time, I learned about the number that each color band on the resistors stands for. I was taught different things about parallel and series circuits.

I went to the 4950th Test Wing several times where they are working on our circuit cards. I watched Mr. Bochrath, the man who is designing the layout, disucss with Mr. McHugh different matters about the card. Mr. Bockrath also showed me different CAD computers he uses and discussed what they do.

I also worked on different computers in our building's control room, where I worked this summer. I was introduced to Wordstar 5 and Cadkey. I helped Mr. McHugh, in the Cadkey system, while he was designing a flowchart. I also got a chance to plot different things I designed in the Cadkey program.

VI. Conclusion

In the summer program, I met many individuals who were in different career fields. I met many electronic engineers, mechanical engineers, aerospace engineers, and computer scientists. These people showed me there projects and talked with me about what they are trying to accomplish. They also talked with me about their college experiences they had dealing with their engineering courses and what it taught them. The things I learned through the summer apprenticeship program taught me valuable lessons and I will remember them in a position that is similiar to those situations.

Final Report

for

Cathie Moore

By: Cathie Moore

Mentor: Mr. Jim Peters

Flight Dynamics Laboratory

August 13. 1990

Thanks to Mr. Peters, Kristen Alexander, Dave Flynt, Giovanni Pagan, and Laurie Hanish.

I. General Description of research

In the eight weeks that I spent working with the Flight Dynamics Laboratory, I learned many new things. I learned how to use four or five new computer systems including Harvard Graphics and Boeing Calc.

With the Harvard Graphics, I drew many data charts for presentations. I used Cadkey to draw pilots and ejection seats. That was my favorite part because I love to draw.

With the Boeing Calc, I compiled a data base of the reports in their library so that in the future my co-workers will be able to find the information they are looking for in much less time. They simply type the subject they are looking for and the computer will tell them where to find the information in their files. Some other parts of the lab have seen my work and would like to have this type of "catalog" in their office too.

II. Detailed description of research

In Boeing Calc, there are many columns. In each column, I put a different type of information so that whatever information a person had they could find everything else about that report or subject. In column A was the report number. In column B was the

date. The other columns had the title and where the report could be located. The last column contained key words which were phrases that described the report.

I used a lap-top computer so that I could easily go from one place of the office to another gathering information. I went up to another office to enter the reports that were there. I could not take a normal size computer back and forth to the other office because it would have been too bulky and heavy.

III. Results

The finished data base contains over 2,500 reports and technical memorandum. It took me about seven weeks to finish the files.

I felt that everyone was willing to help me at any time I needed it. I felt like a part of the group. They never excluded me at all because they thought I was not an important part of their office.

I think this program is a very worthwhile one. It should keep going on in the future. I feel really honored that I got chosen to participate in this program and I hope that I represented my school well. I hope that someone from my school can participate in this program next year.

I believe that people should get a chance to be

exposed to our country's government. I am also happy that our government gets a chance to see what our generation will have to offer to our country.

IV. Other interesting observations and lessons learned from summer experience

It was a real change working with people who were not my age. I had to learn how to act more maturely. I felt it was a challenge for me and I have always loved a challenge.

Most people accepted me as just another worker. One women that I worked with took me out to lunch a few times. She brought me along and treated me as if I was just as important as her and her friends.

This summer has been the biggest change for me in my life. I have grown up so much. It was like another world for me. I had never been put with people who were older than me and expected to work with them. I am a member of Cross Country and Track and I was always the leader of my teammates no matter if they were younger or older than me. It was different working with people who have been around much longer [illegible] much more than [illegible] has been the most educational summer of my life

PROJECT INSTRUMENTATION

Written by
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August 17, 1990

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The Instrumentation Group plans, schedules, establishes, and determines all measurement requirements for all structual integrity test programs. This Group also designs test instrumentation systems and provides for the selection, calibration, and installations of all tranducers required for data acquisition and control. The Group is also responsible for intepreting and analyzing all data acquired.

The Instrumentation Group, made up of engineers and technicians, is in charge of mapping out coordinates for and installing strain gages on many different types of structures. The gages are preset to a certain amount of ohms and any change in resistance can be linearly related to strain. The engineers determine the positions of the gages and how they should be aligned. The technicians place the gages and secure them to the material. They also make the necessary cables to hook up the sample to signal conditioning and a readout device, usually a digital computer. All of this is done to check the strength and reliability of different materials. When the material reaches

its limit, all the information is stored in a computer (the computer stores information from the start to the finish of the test). This data is then transferred to the Data Acquisition and control Group where it is processed and acted upon. Therefore, the Instrumentation Group could be known as the information and data gatherers.

There are a number of things that must be done on a almost daily basis in the technician's laboratory. This includes the application of gages, the preparing of the cables and the soldering of wires to the gages. For the most part, all the gages are applied in the same manner. The differences come when the material is being tested in more than one area. When preparing materials for the simple tests, pulling in tension and/or being shot at, not much is required other than keeping the surface clean and having enough pressure on the adhesive. However, when changes in temperature are apparent, a stronger adhesive which can sustain higher and lower than normal temperatures is needed. One such pair of adhesives are M-Bond

AE-10/15 and M-Bond GA-2 (copies of instructions included in the Appendix). Both of these require the gages and materials to be baked or cured at a higher temperature. This causes no damage to the gage or material, it only allows for the glue to dry. Contact cement is also used (sheet included in the Appendix). The surface of the material must be cleaned and properly lined to insure that the gage gives an exact reading. The cables, or wires, must be measured to a certain length, stripped and tinned on the ends. Tinning is where the ends of wires are twisted and then covered with solder by a soldering iron. Lugs or connectors are soldered onto the ends of some wires so they can be hooked into a computer. They are only necessary when dealing with direct connections with a signal conditioning module. Standard connectors are soldered onto one end and allow communication between two different machines (input and output). Soldering connects the cables to the gages and connectors. There are different ways of soldering wires: the standard soldering iron, the silver solder gun, and the torch. Flux, which allows the

solder to flow when melted, comes in different types. There is the usual solder flux, then silver flux, lead flux and aluminum flux. All of this is done with almost flawless accuracy. The finished products are sometimes things to be marveled at. The technicians work daily completing their tasks for the engineers.

After spending the past eight weeks within this group, I have found out that there is very little difference between the engineers and the technicians. It is more of a cooperative partnership than anything else. The technicians are more involved with the hands-on work of instrumentation, while the engineers have a more theoretical background. However, both the technicians and the engineers have the experience and knowledge of the practical application of instrumentation. When the group is operating at peak efficiency, projects move swiftly and problems rarely develop. The Instrumentation Group, as a whole, is more like a family.

There are times when certain people in the group [illegible] laid back and not as tense as some of the others. [illegible]

technician crew seems relaxed, while a few engineers never let themselves go. On a normal day, one can expect a few jokes from the technicians and some of the engineers. The most relaxed engineer would be a recent graduate, who has been in the Instrumentation Group since January, (in my opinion). He frequents the night life after a good day at work. With such a balance existing, it is easy to see why the group moves in such a fluid manner.

Appendices can be obtained from
UNIVERSAL ENERGY SYSTEMS, INC.

1990 Air Force Office of Scientific Research

High School Apprenticeship Program

Stan Wall, Apprentice

Mike Stringer, Mentor

Flight Dynamics Laboratory

August 10, 1990

ACKNOWLEDGEMENTS

The first I learned of the Air Force High School Apprenticeship program was from a teacher's casual mentioning in class. My first thought was of disinterest, but my second thought was that maybe it would be a great source of money as a summer job! After learning more about the program, though, I realized that aside from monetary rewards, the program offered me a great chance to apply my own knowledge usefully and gain valuable experience in an engineering area. With this realization, I looked forward to my participation in the program. There are many people I wish to thank who have helped make my experience enjoyable as well as enlightening. I would first like to thank Mr. Mike Stringer for having me as his apprentice. He has been an excellent teacher as well as a helpful colleague. I must also give him credit for making Aerospace Engineering the newest addition to my choice of college majors. Mrs. Bonnie Buddendeck, my high school chemistry teacher, for introducing the Apprentice Program to me and giving me her recommendation, as well as inspiring the scientist within me. Mrs. Rhonda Duvall for her much-appreciated help in revising this report. Mr. Kevin Langan for his assistance in using the OTIS computer program (and for being a Penn State alumnus). Mr. Carl Tilmann and Lt. John Cannon for their technical assistance in operating the various computers. Mr. Ron Gord for providing me the opportunity to work on the Beta project with Mr. Stringer. Other workers of the Flight Dynamics Lab for their assistance. Ms. Wendy Choate (the other student apprentice in Building 450) for providing occasional computer assistance as well as her friendship. Mr. David Johnson and Mr. Val Dahlem for

their continual support. Mr. Adolph Harris, Mr. Milton Danishek, and the UES coordinators for creating this program and selecting me to be a part of it. I give thanks to the many other WPAFB coordinators who helped bring the program to the base.

INTRODUCTION TO RESEARCH

My work as an apprentice this summer involved three different projects. Assisting in the revision of a manual for a computer program was the first project assigned to me. Although not scientific or technical in nature, the work on the ENTRAN manual did require me to perform tasks accurately and promptly. After the ENTRAN manual, I chose, with the encouragement of Mr. Stringer, to enrich myself by attempting a problem set from an aerodynamics textbook. In solving these problems, I became acquainted with the basic terms, properties, and equations of motion that govern the flight of aircraft. This made the aerospace work that followed easier to comprehend since I had a basic foundation of flight. This understanding was put to use with the Beta Project which dealt, basically, with horizontal takeoff and landing (HTOL) booster and orbiter vehicles. This project, which will be described in detail later, required that I learn how to operate a computer program called OTIS to produce trajectories of boosters and orbiter vehicles that maximized range or payload weight. The final project that I assisted with was the Silent Attack Warning System (SAWS). This project involved missile flight tests to test SAWS. My work with this project involved collecting and compiling data from missile launches. After data was compiled into plots, the plots were compared to theoretical plots of the same launches. Comparing the flight test results to theoretical plots would permit more accurate missile-tracking by predicting missile behavior. This project allowed me to use the skills learned with the ENTRAN and Beta projects, such as creating data tables, running OTIS, and using the computers.

PART 1 - ENTRAN MANUAL

Description

The first task I was assigned to was helping in the completion of a manual for a computer program called ENTRAN. Initially I had to recreate flowchart diagrams from the originals. This involved using a word processor, a desktop publishing program called Publisher's Paintbrush, an optical scanner, and a laser printer. Being very computer intensive, I found the work very challenging and very rewarding.

Methodology

Steps involved in the process were [1] entering the flowchart text using PC Compose, [2] printing out the text with the laser printer, [3] scanning the text into the Paintbrush program, [4] adding symbols and lines using Paintbrush, and [5] printing out the final chart using the laser printer. [SEE FIGURES 1 and 2] After completing the necessary flowchart, I proofread the new copy of the text portion of the manual scanning for overlooked errors. Having proofread the manual, I printed out page numbers and assisted in renumbering the manual. Since the page numbers had changed from the previous version of the manual, a revised table of contents was required. Using Prime Word on the computer terminal, I corrected the table of contents and printed a new copy.

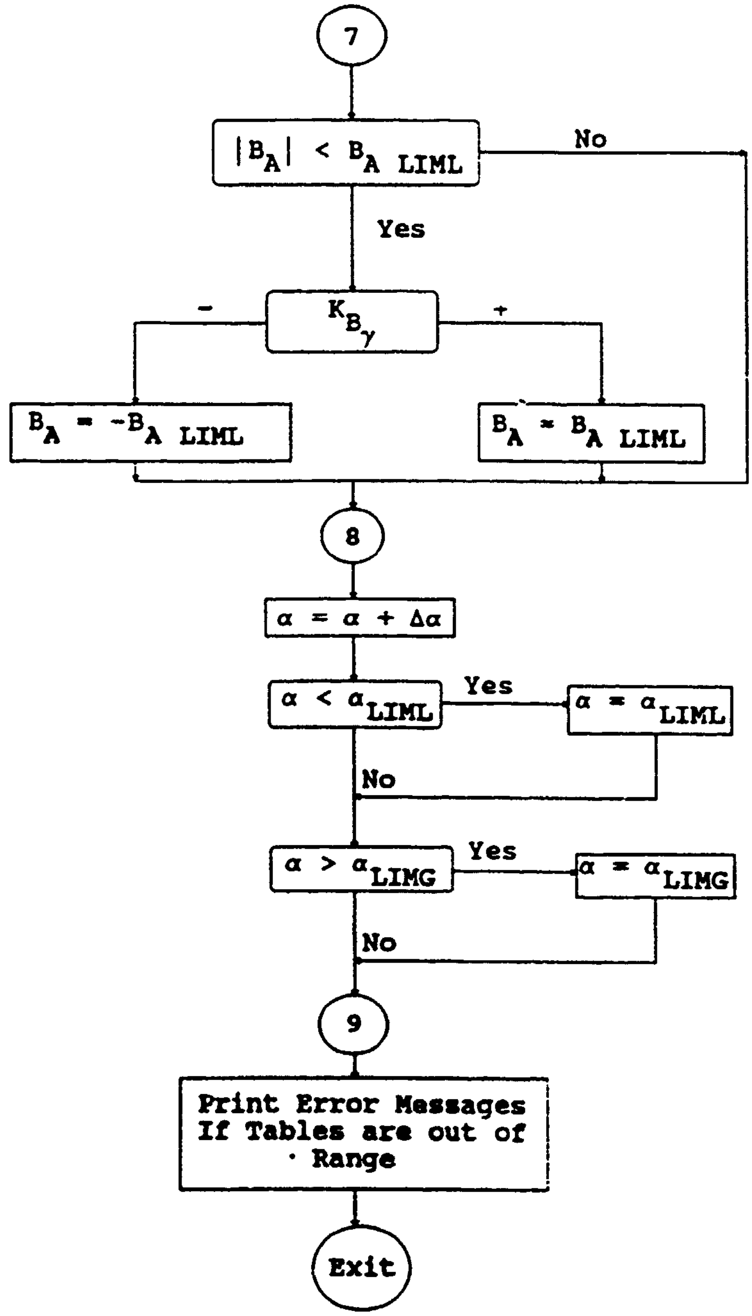


FIGURE 1 - SAMPLE ENTRAN FLOWCHART #1

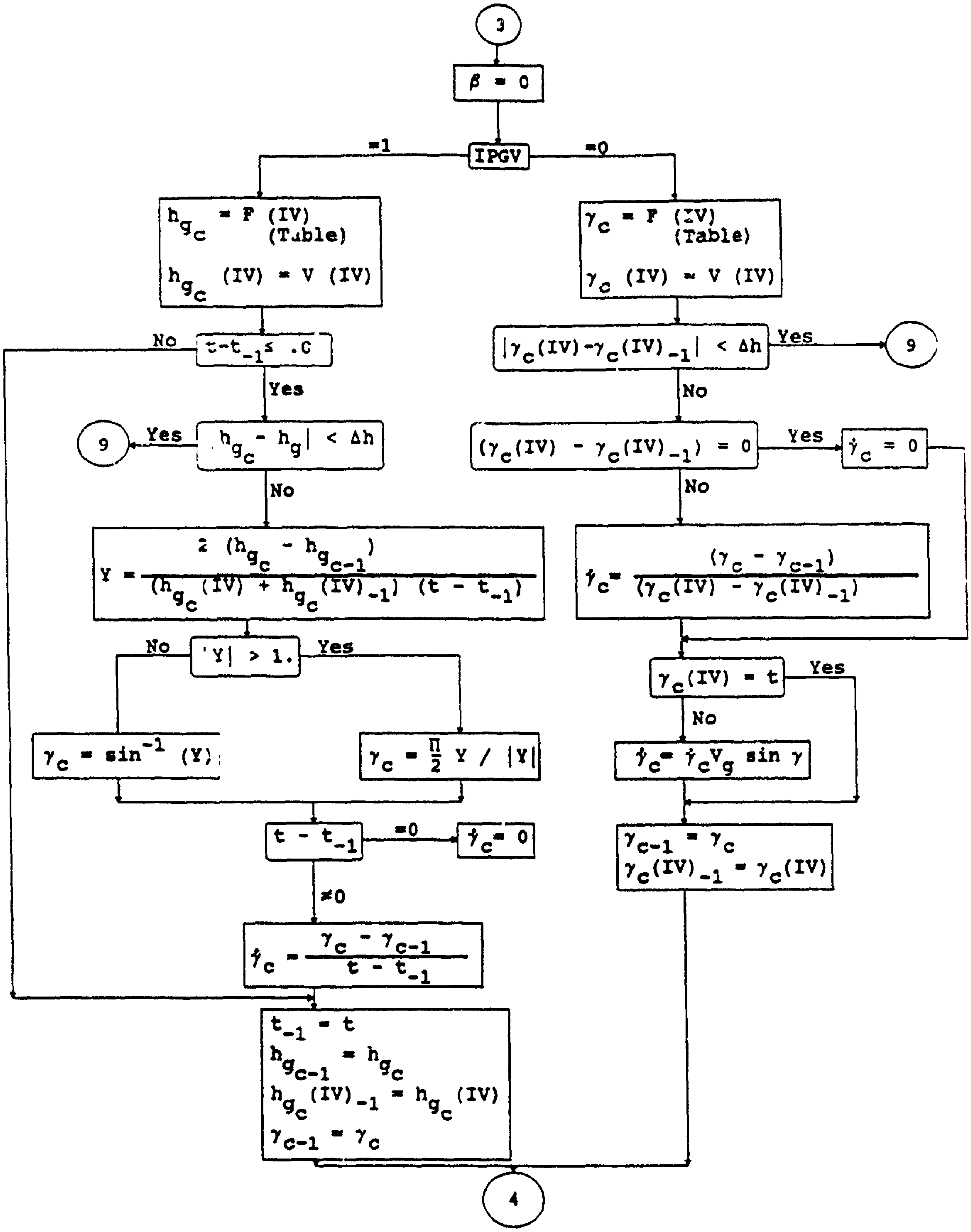


FIGURE 2 - ENTRAN FLOWCHART #2

Results

Finally, all of the revisions were complete, and the manual was given one last proofreading. It was then compiled and prepared to be sent to the printer. Although revising and compiling the manual may seem somewhat mundane, I felt a sense of accomplishment since it was my first completed task.

PART 2 - AERODYNAMICS PROBLEMS

Description

The next task I performed was somewhat self-motivated. In order to familiarize myself with aerospace engineering, I read through a book titled Aerodynamics, Aeromechanics, and Flight Dynamics by Barnes W. McCormick. In the text book I found a group of problems dealing with equations and properties of force, lift, thrust, drag, and weight. Some of the problems involved concepts of physics as well. I attempted to solve a problem set [FIGURE 3], and with some assistance I was successful.

Methodology

The equations need to solve the problem set were provided in the chapter by the author. The equations included:

(1) $$\theta c = \frac{(T - D)}{W}$$

(2) $$w = TS$$

(3) $$P = T (S / t)$$

(4) $$P_{reqd} = DV$$

(5) $$P_{avail} = TV$$

(6) $$W(V\theta_c) = P_{avail} - P_{reqd}$$

(7) $$V_c = V\theta_c$$

All of the variables used in the equations above are defined in the appendix at the end of this report. Using initial assumptions and

given information to substitute into the equations above simplified the solving of the problems.

The first problem [FIGURE 3a] dealt with calculating the rate of climb of an airplane. The thrust-to-weight ratio (T / W), lift-to-drag ratio (L / D) and velocity were the given values. Assuming that the the airplanes initial rate of climb was zero, I made lift (L) and weight (W) equal to each other. Then by substituting equations (4) and (5) into equation (6), I arrived at a value for $W(V\theta_c)$ in terms of thrust (T) and drag (D). I divided the equation by W - substituing the value of (T / W) in the process - to solve for angle of climb. Using equation (2) I substituted (L / W) for (L / T). Since my initial assumption was that L and W were equal, I was able to produce a solution. The final step in the process required the problems units to be changed from meters per second to feet per minute, so I converted the solution to get a final answer for the problem.

The second problem was different in that it dealt with the physical property of equilibrium. [FIGURE 3b] The diagram provided showed a ball resting in a concave track and another ball resting on a convex track. The problem asked to discuss the equilibrium and stability of the two ball and track systems. I concluded that both problems were in equilibrium since the balls were pictured as being stationary. However, only the concave system was stable. I arrived at this conclusion by determining the theoretical result of disturbing each system. If disturbed, the ball on the convex track would roll off and the system would not recover. The ball on the concave track, however, would return to its original position. Thus, that system was stable.

(A) Calculate rate of climb for an airplane having a thrust-to-weight (T/W) ratio of .25 and a lift-to-drag (L/D) ratio of 15.0 at a forward velocity of 70 m/s (230 fps). Express Vc in meters per second and feet per minute.

T/W = .25   P avail = TV = 70 T

L/D = 15.0   P reqd = DV = 70 D

T/W * D/L = .25 * 1/15 = .01666   D/W = .01666 L/T

W = TS

S = W/T = 1/.25 = 4   W = 4T   T = W/4

$$
\begin{aligned}
W(V\theta c) &= \text{P avail} - \text{P reqd} \\
&= 70\ T - 70\ D \\
(V\theta c) &= 70\ (T/W) - 70\ (D/W) \\
&= 17.5 - 1.1662\ (L/T) \\
&= 17.5 - 4.66\ (L/W) \\
&= 17.5 - 4.66 \\
&= 12.83\ \text{m./sec.}
\end{aligned}
$$

(B)

Equilibrium   Equilibrium

Stable   Unstable

(C) W = F * D   W = 0, Since no distance vector is given

F = 6N

Time = 4 hr

FIGURE 3 - PROBLEMS FROM AERO TEXTBOOK

The third problem I attempted [FIGURE 3c] described a student pushing against a wall with 6 newtons of force for a period of 4 hours. The problem asked for the amount of work done. Assuming the wall to be stationary, I concluded that there would be no work done since work is a function of force and distance but not time.

Results

These problems ranged from very complex to relatively simple. In the first problem, I learned of the various forces which must be accounted for in the flight of an aircraft. I also gained practice in solving a problem using a system of equations, and I gained more experience in converting to the conventional units used in aerospace engineering. With the equilibrium problem, I learned to solve a problem by theoretical cause and effect. The third problem basically involved applying the correct formula for the variables given. Since there was no distance variable, no work resulted.

PART 3 - OTIS & SAMPLE PROBLEM

Description

The major portion of my work on the SGI computer revolved around the use of OTIS (Optimal Trajectories by Implicit Simulation). This computer program works to find the best - "optimal" - solution to the given problem based on the input data. The data files consist primarily of a file which describes the vehicle itself and its characteristics, and a file called the input file. The input file is the file which describes the vehicle's particular mission: fuel on board; starting location, velocity, and heading; angle of attack; phases; and stages. Those are just a few of the many intitial conditions which can be set. Also, controls, placards, and bounds can be set to force the vehicle to perform within certain limits. An objective, or final condition, is set within the input file as well. If all initial values are set correctly and within reason, and if the objective condition is not impossible or illogical, OTIS will find the optimal path for the vehicle to follow.

I found learning to use OTIS - an extremely complex ε oowerful program - a very formidable task. After scanning the manuals to gain a better understanding of how the program works, I was given a sample problem to try. The basic objective was to take a generic launch vehicle from a given altitude and velocity into a low earth orbit (LEO). As the amount of payload on board increased, the initial launch weight (ILW) and initial orbit weight (IOW) also increased. The intent was to get the vehicle to orbit with the greatest payload weight, Wp.

Methodology

Finding the best solution to this problem involved several steps. I started out with an initial "best guess" for the payload weight. Based on this payload weight, I calculated ILW and IOW. After OTIS was run with the new orbiter weight (IOW) value, an optimal trajectory was determined. However, the final weight to orbit (WTO) determined by the trajectory and my own IOW differed (OWD): the orbiter had excess fuel when it entered orbit. Thus, I had to adjust my Wp to compensate for this excess. I adjusted Wp by adding 1.25 times the OWD value. Then, I re-ran OTIS with the revised Wp, ILW and IOW values to obtain a new optimal trajectory. If OWD was still not less than 100, I adjusted the value of Wp again and re-ran OTIS until the value was less than 100. When the difference (OWD) became minimal - less than one hundred pounds in this case - I had found my maximum payload and the optimal trajectory [SEE FIGURE 5] for the orbiter.

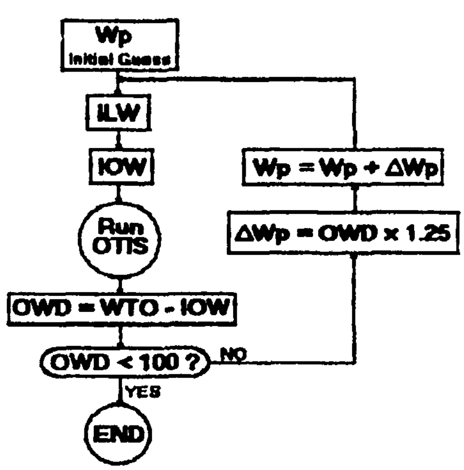


FIGURE 4 - ITERATING AN OTIS TRAJECTORY

What I learned later is that the manual recalculation I had just performed was called an "iteration". As I recalculated each new IOW value (performed another iteration), the difference between my new IOW and the WTO result obtained from OTIS decreased (the function was converging). The flow chart below details the process of solving this iterative problem.

Results

After completing the necessary iterations, I arrived at a maximum payload for the orbiter. When I completed seven iterations [shown below in FIGURE 5], the OWD reached a value of 38.

```
Wp  = 120,000 (lbs.)      WTO = 308,450
ILW = 672,200                 - 229,900 IOW
IOW = 229,900             -------------
                                 78,550 OWD

Wp  = 220,000             WTO = 350,917
ILW = 772,200                 - 329,900 IOW
IOW = 329,900             -------------
                                 21,017 OWD

Wp  = 246,000             WTO = 361,800
ILW = 798,200                 - 355,900 IOW
IOW = 355,900             -------------
                                  5,900 OWD

Wp  = 253,400             WTO = 364,895
ILW = 805,600                 - 363,300 IOW
IOW = 363,300             -------------
                                  1,595 OWD

Wp  = 255,390             WTO = 365,724
ILW = 807,590                 - 365,290 IOW
IOW = 365,290             -------------
                                    434 OWD

Wp  = 255,950             WTO = 365,957
ILW = 808,150                 - 365,850 IOW
IOW = 365,850             -------------
                                    107 OWD
```

```
Wp  = 256,950          WTO = 365,988
ILW = 808,250              - 365,950 IOW
IOW = 365,950          -------------
                                  38 OWD
```

FIGURE 5 - THE ITERATIVE PROCESS

Having met the stopping condition, I had a final payload weight of 256,950 lbs. This value ended up being more than twice the value of my initial guess for IOW of 120,000 lbs. From this first OTIS problem, I gained insight on the methods OTIS uses to solve trajectories. This problem also exposed me to the iterative process which gives OTIS its powerful problem solving capability. With this knowledge, I was ready to take on a major task involving OTIS: the Beta system ferry mission.

PART 4 - BETA SYSTEM

Description

The Beta Ferry project was the task which required the greatest use of OTIS. The Beta system is a two-stage launch-to-orbit vehicle which, like an airplane, takes off in a horizontal position [FIG. 6B]. Located within the underside of the booster is another vehicle called the "orbiter" [FIG. 6A]. The orbiter has a cargo bay for delivering satellites or other instruments into space. After the Beta system takes off and reaches a designated altitude, the orbiter is released [FIG 6C]. The jet powered booster vehicle then returns to land in a airplane fashion [FIG 6D], while the orbiter, propelled by rocket engines, continues until it reaches orbital altitude [FIG. 6E]. After completing its specified mission in space [FIG. 6F], the orbiter returns to Earth [FIG 6G] to land in the same horizontal manner as the present day space shuttle [FIG 6H]. There are several advantages of the Beta concept over the current space shuttle. Not only does the Beta system combination allow conventional airplane-style takeoffs and landings, but it eliminates the need for external rocket boosters or fuel tanks. Instead of those expensive disposable boosters and fuel tanks, the Beta system features a totally reusable booster vehicle. Use of a horizontal takeoff vehicle cuts down on the dangers associated with vertical shuttle-type takeoffs.

My work with the Beta system involved finding maximum range of the booster vehicle carrying the empty orbiter. OTIS was given the vehicle's starting conditions such as weight, velocity, angle of attack (α), and altitude. The mission began at takeoff, progressed through the

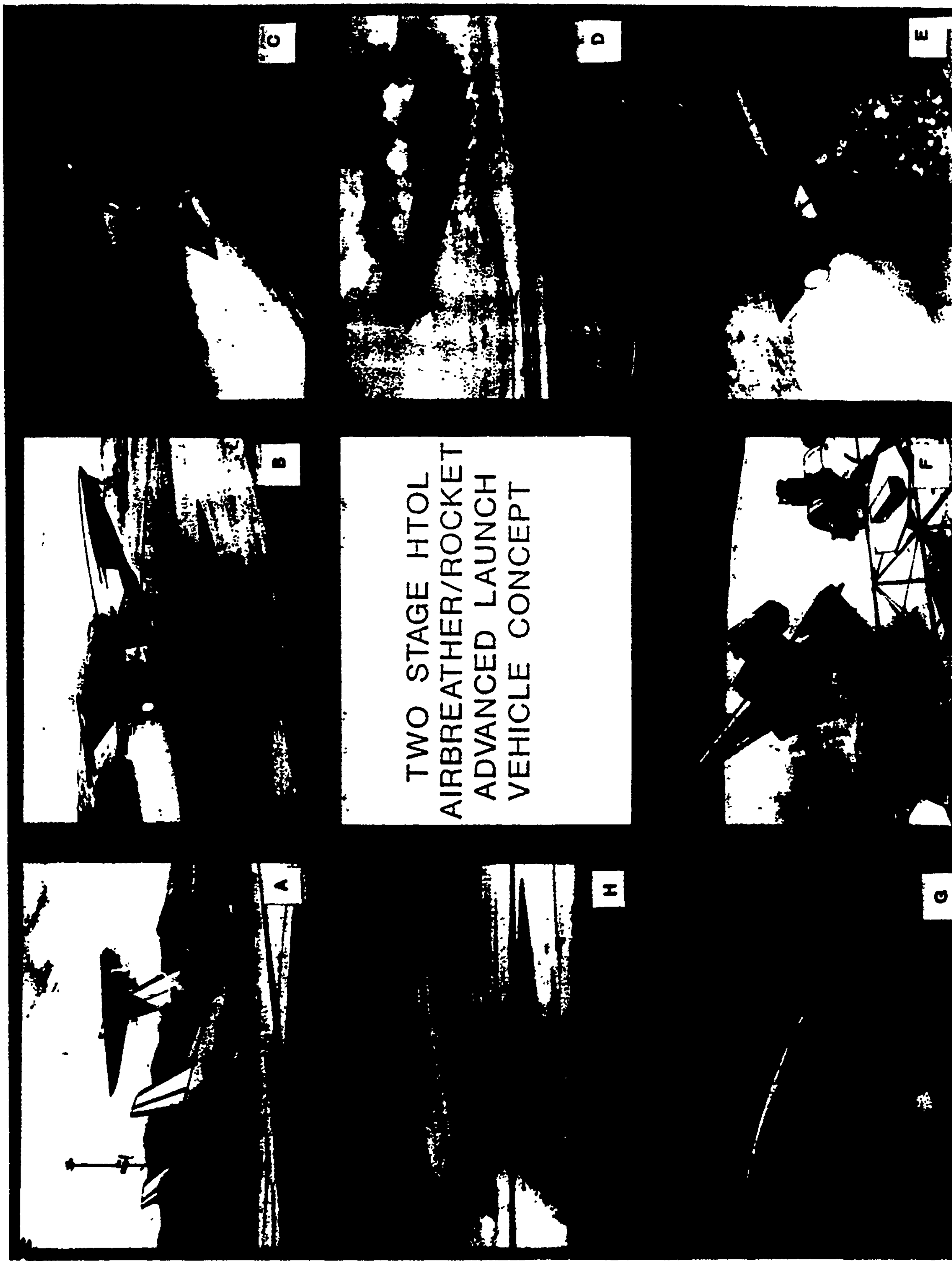


FIGURE 6 - PHASES OF A BETA SYSTEM MISSION

ascent to cruise altitude, and then continued in a cruise-climb (low rate of climb) until it reached the stopping condition. The purpose of this test of the Beta system was to learn the efficiency of the booster vehicle in transporting the orbiter from place to place, such as from one launch runway to another.

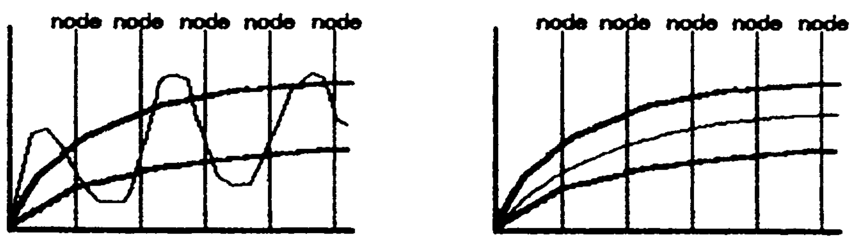
Methodology

I tested the Beta system with three different values for initial weight. The procedure used in testing each system weight was the same and is described in the following section.

The first step in the process was creating an input file for the mission. I used a file that had been prepared previously, but initial values and controls had to be modified. In order for the vehicle to get off the ground, initial velocity had to be equal to the takeoff velocity for the vehicle. In the input file, OTIS was instructed to only control α. In this case, α was limited to of range of -5 degrees up to 20 degrees. A placard - or boundary - was placed on altitude as well: the minimum and maximum values were 0 feet and 50,000 feet. In arriving at a trajectory for maximum range, OTIS performed several time-consuming iterations; due in part to the strict boundaries that were imposed. When I examined the output data for the trajectory, I noticed that for the first 20 seconds, the altitude of the Beta system was a negative value: the Beta system was digging a hole in the ground and then coming out again. This problem was perplexing since the lower boundary for altitude had been set at zero. With the assistance of Mr. Stringer, we explored the causes or remedies for this problem. We attempted to increase the initial value for α, but the system still went underground

for a time period. Finally, we concluded that the problem was a result of the way in which OTIS was checking compliance of values with their boundaries.

This problem arose because of a lack of nodes in our trajectory. A node is a point at which all values must meet the conditions set by the given function. In my trajectory I used fifteen nodes spaced evenly throughout the entire mission, so OTIS was breaking the boundaries at points that lay between the nodes. The program was finding a trajectory but it was not the most "optimal" trajectory.



The two plots above show possible trajectory ouput using OTIS. The two dark lines on each plot show the upper and lower bounds placed on a sample mission. Both plots would be essentially acceptable since the boundary conditions are met at each node. However the first plot breaks the constraints between every node, while the second plot does not violate the constraints at all. In order to force OTIS to not let the Beta system go underground, we needed to add more nodes. This addition would force OTIS to check compliance with the constraints more often. If the first sample plot above had more nodes, OTIS would have rejected the trajectory plotted.

In order to add more nodes, I thought it would simply be a process of changing the value in a variable: from 15 nodes to 50 nodes in this

case. However, after making that attempt, OTIS produced an error message. The program did not want to accept the increased number of nodes. Even after splitting the trajectory up into three phases of 15 nodes each, running OTIS still did not produce acceptable output. The first phase of the trajectory was fine, but between the first and second phases the data was not continuous. To solve this problem I instructed OTIS in the input file to force continuity between the phases. However, this was unsuccessful also. Concluding that every option had been attempted, we concluded that there was a problem with the version of the OTIS program that we were using. Mr. Stringer copied a differnet version of the program to the computer I was using. Then I attempted to run the trajectory woth the original 50 nodes. The iterating of the mission took a very long time since there were over three times more nodes to check. However, OTIS eventually produced an optimal trajectory. With that trajectory, I had my solution for maximum downrange of the Beta system for the test weight.

Results

The maximum range of the Beta system was 487 miles based on the optimal trajectory produced by OTIS. After acheiving this solution, I used the data from OTIS to create a plot of altitude vs. range. This plot conformed with the predictions made before the test. The vehicle took off and. over the course of about 75 miles downrange, reached a cruise altitude of 25,000 ft. For the rest of the flight, the Beta system was in a cruise-climb. At the termination of the mission, Beta had reached an altitude of about 33,000 ft and a range of 487 miles.

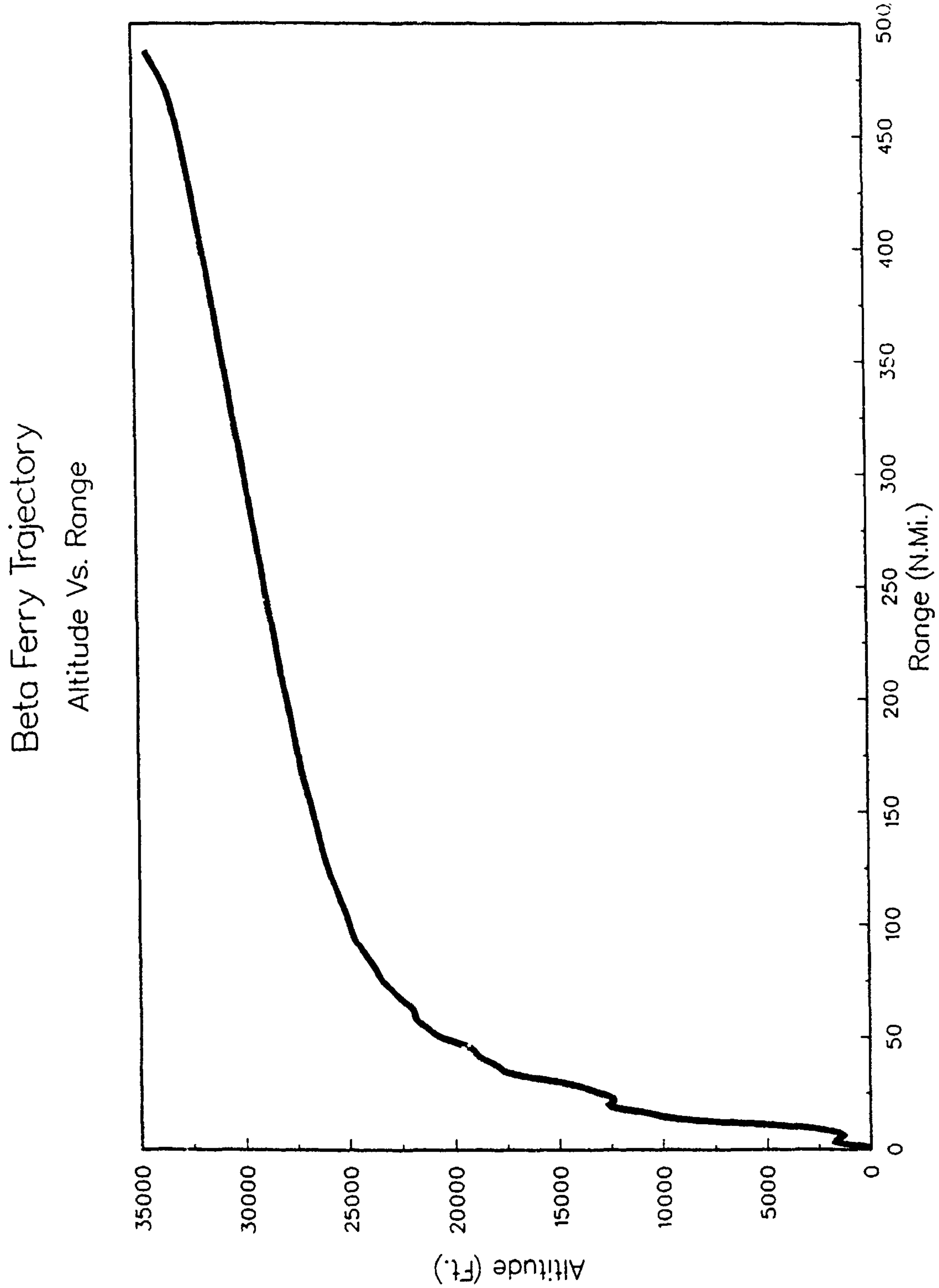


FIGURE 7 - PLOT OF BETA FERRY MISSION

The value for range was very acceptable, since it exceeded what was originally predicted.

PART 5 - SAWS PROJECT

Description

The final task I was assigned I found to be the most rewarding. It involved gathering data from flight tests for the Silent Attack Warning System (SAWS) project. The part of the project that I was involved in dealt with video tapes from missile launches at White Sands Missile Range (WSMR). The tapes consisted of visual tapes of the launches and radar tapes which tracked the missiles, while displaying statistics such as altitude, velocity, location, etc.

Methodology

To record this data, I created a chart with areas to record the mission information; launch, burnout, and impact times; and a data table of statistics. [SEE FIGURE 8] While viewing the visual tapes, I recorded the times of the missile's launch, burnout, and impact. Then, while viewing ·he radar tapes, I recorded the statistics - altitude, velocity, location, etc. - for those same times, as well as half-second intervals throughout the flight of the missiles.

When all data from the tapes was gathered, I began the second step in this task. I entered the data from all of the missions into the computer as data files. Using the EZ-3D plotting program, I compiled plots - such as velocity vs. time, and altitude vs. time - of the launches After the plots were completed, the third step was to compare them to plots made using OTIS to show how the theoretical trajectories appeared.

SAWS Flight Test Data

#___

DATE ____________
SITE ____________
PROJECT ____________
MISSION ____________
MIDI COURSE ____________
START ____________
DESCR ____________

	TIME
LAUNCH	
BURNOUT	
IMPACT	

* indicates burnout data on chart below

TIME	LON (deg)	LAT (deg)	ALT (ft)	GRD SPEED (kt)	GRD SPEED (ft/sec)	2DSEPV (ft/sec)	VEL (ft/sec)

FIGURE 8 - SAWS FLIGHT TEST DATA CHART

Results

Although the SAWS project is still continuing, preliminary data has allowed some conclusions. The major observation that has been made at this time is that the missiles from the flight tests consistently achieved higher velocities than that predicted by the OTIS plot. Possible reasons for this difference in velocities have been attributed to lower thrust values for the OTIS trajectory. However, the flight test plots are very similar to the OTIS plot after engine burnout. This could be proof that the drag in both the actual and theoretical plots are equal since the missiles are slowing down at the same rate. When all data for the flight tests and plots are compiled, more substantial conclusions will be made.

This challenging task was very fulfilling since it involved several linked, complex steps. I found myself using the skills learned from ENTRAN and practice with OTIS. It was also a task where I was able to work on many aspects of a project.

CONCLUSION OF RESEARCH

In participating in the High School Apprenticeship Program, I was involved in three different projects. In each case I feel I completed each task or contributed to the associated project with my greatest effort and concentration. To conclude this research, I will summarize the task completed for each project. With the ENTRAN manual, I was able to greatly assist in revision of figures, general compilation, and proofreading. As of August 9, 1990, the new, revised manual had been published and distributed. For the Beta system ferry mission, I was able to assist in producing a trajectory showing maximum range of the vehicle. This project involved learning to use and understand the OTIS computer program. My involvement with the SAWS project has also delivered results. Although the project is still continuing, I was able to gather data from the video tapes and compile preliminary plots of the results. I am proud of the research I have done this summer, and the contribution that my research has provided.

OBSERVATIONS AND EXPERIENCES

Orientation and Base Tour

The first phase of my apprenticeship was orientation which included a tour of WPAFB Area B. Although the tour took place for just part of one day, it exposed me to some of the many interesting labs and facilities located at the base.

The flight simulators and labs were the first stop on our tour. There, we watched a film of what goes on at the lab and toured the simulators themselves to get a first-hand look at what a pilot would see during an actual simulation. Behind the scenes, we saw the computers that control the actions and responses of the simulators. Through the use of computer graphics workstations, operators in the control room are able to monitor the simulation in progress.

Next, we visited the structures lab, where we viewed an F-15 body undergoing tests for structural integrity. The plane was suspended within a steel framework. Thousands of wires attached to predetermined points on the plane's surface wove their way through a system of pulleys and control arms. When the system received input from a computer, it would respond by pulling or releasing certain groups of wires. Thus, actual stress loads that a plane would experience during flight could be simulated in the laboratory. Also at the structures lab were two large rooms enclosed by thick, insulated metal walls. Their oven-like appearance disclosed their purpose: they were used to expose various components or materials to extreme levels of heat. After heating objects to certain levels, the objects would then be retested to observe if there had been any change in strength.

Our next destination was the landing gear lab. At this lab, tests are performed on all aspects of landing gear systems: tire cross sections, wheel design, support and suspension systems, and the materials which make up each component. Some current and past projects include comparing strength to weight for different metals and alloys, testing landing gear braking systems, as well as load bearing limits for different parts of the landing gear.

After the landing gear lab, we visited the water tunnel. This tunnel, like wind tunnels, exposes test models to a flow to observe aerodynamic qualities. However, by using water, the water tunnel is able to subject models to a flow for prolonged lengths of time. Located on the surface of the model being tested are several outlets to allow the release of colored dye. The dye flows over the surfaces of the model so that uneven or unstable flows can be studied.

The water tunnel lab completed the base tour and we returned to Building 450. Over the course of the next few days, I became acquainted with the facilities of my building. We toured the wind tunnels and saw a wind tunnel test in progress. I also became aware that many groups that work in Building 450: Flight Propulsion, the X-29 team, the F-15 Short Takeoff and Landing/Maneuvering Technology Demonstrator (STOL/MTD) team, and others.

<u>Computers</u>

In revising the ENTRAN manual, I was required to use the computers to complete part of my work, and I soon learned that the vast majority of the rest of my work would involve using computers in some way, shape, or form. The computers I worked with were IBM compatible PCs, Silicon

Graphics Iris (SGI) workstations, and terminals linked to the Prime mainframe. Familiarity with the PC from past experience at home and school proved to be helpful. I had no problems in booting up or operating the computer and I quickly picked up on how to run the programs I needed. The SGI computer was the most fascinating of the computers I used. It is an extremely powerful system that is able to display complex graphics and manipulate them in virtually any manner. Learning to access files and directories, editing files, and running programs was simple, thanks to its graphics-oriented windows environment. It became the computer on which almost all of my work using the OTIS program was done. The other computer which I used was the Prime. Being a mainframe, it is also a powerful computer but it lacks the flashy graphics of the SGI. On the Prime, I learned to log in and out and how to run Prime Word (word processing program) and EZ-3D: a program with which I would soon be creating many plots. Through my use of the computers described, I learned that they are definitely a part of engineering and any other technical field.

Conclusion

One of the most rewarding aspects of my job this summer was seeing the tasks assigned to me progress from simple, busy-type work, to more complex, computer intensive work, and finally to a project where I worked independently most of the time and used different tools. I enjoyed the feeling of responsibility and the knowledge that my work was a contributing part of a larger project. I gained invaluable experience in working with others as well as using my own insight to solve problems on my own. During periods when I was working independently, without

supervision. I motivated myself to work efficiently and with accuracy. Overall, I feel my participation in the High School Apprenticeship program was an excellent experience. The new experiences and lessons learned in responsibility and interactions with others can only help in my continuing and future growth.

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APPENDIX : NOMENCLATURE

SYMBOL	DESCRIPTION
D	Drag (lbs.)
ILW	Initial Launch Weight (lbs.)
IOW	Initial Orbit Weight (lbs.)
OWD	Orbiter Weight Difference (lbs.)
P	Power (ft. lbs./sec.)
P avail	Available Power (ft. lbs./sec.)
P reqd	Required Power (ft. lbs./sec.)
S	Distance (ft.)
T	Thrust (lbs.)
W	Airplane weight (lbs.)
w	Work (ft. lbs.)
Wp	Payload weight (lbs.)
WTO	Weight to orbit (lbs.)
V	Velocity (ft./sec)
Vc or $V\theta c$	Rate of climb (ft./sec)
α	Angle of Attack (radians)
θc	Angle of Climb (radians)

1990 AFOSR/UES Apprenticeship Program

Flight Dynamics Lab, Wright Pat AFB

Douglas P Wickert

Mentor: William Lindsay

June 18 - August 10, 1990

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I would like to take this chance to extend my gratitude to all the people in the Flight Dynamics Lab who made my apprenticeship profoundly successful. Without a doubt, the methods, processes, and development techniques they have shown me in the past eight weeks will stay with me through any career I choose. In particular, I want to show my appreciation for Mike Patzec in Cockpit integration/Crew Systems, Deiter Multhopp and William Blake in the Design Prediction Group of Control Dynamics, and Donald Gum and Ralph Korthauer of FIGD. I also owe many thanks to the Software Design Group of FIGD including Michelle Braswell. Harold Toomey, Jim Lowenski, Larry Mutscheller, and Juan Cauldezo. Finally I would like to thank my mentor William Lindsay who made the arrangements for my participation in the plethora of various departments of FIG. These people and many others who are impossible to record made my apprenticeship in Wright Patterson's Flight Dynamics Lab the greatest experience of my life. I owe them everything!

INTRODUCTION

The Flight Dynamics Laboratory consists of many different divisions including FIG (Flight Control Division.) Likewise, FIG is divided into several departments. My mentor, William Lindsay of FIGL (Control Systems Development), arranged for me to spend two week 'tours of duty' in FIGC (Control Dynamics), FIGD (Flight Simulation Laboratories), and KT (Cockpit Directorate.) The results of my work with the various branches of FIG and KT will be arranged chronologically starting with KT, then FIGC, and finally FIGD where I spent four weeks. My work with each of the branches differed greatly and covered a wide range of characteristics which allowed me to participate in almost every stage of research and development. While with KT, I looked at cockpit systems with largely a futuristic, long range goal and researched how they would make the pilot's job easier. While in FIGC I participated in some hardcore aerodynamic engineering and analyzed ventral fin configurations that could be flown on a test-aircraft within the next couple months. And while I worked in FIGD I wrote computer graphics programs to be used in the flight simulators. Thus I was exposed to a large spectrum of methods and techniques and was able to see how one step contributes to the work being done in other areas.

RESEARCH IN KT

As new aircraft, avionic, and weapon systems are constantly being developed, the pilot's job grows increasingly difficult and new ways of removing the demands on the pilot must be developed. This is the research being done in Cockpit Integration. To insure the pilot's survivability in a combat situation, as many systems as possible should be automated, all information should be displayed in an effective, easy manner, and all controls should be easily manipulated by the pilot. Each of these areas are presently being pursued in KT. I participated in a study involving the set-up of format displays and the different methods of accessing these diplays.

Modern fighter aircraft have four seperate displays in the cockpit: one HUD (Heads-Up Display), and three MFD's (Multi-Function Display.) The HUD sits in the pilot's line of sight as he looks out the cockpit and displays airspeed, altitude, compass heading, attitude by means of an artificial horizon, and "G's" being pulled by the aircraft and pilot. The MFD's are heads-down displays surronded by bezel switches and are capable of displaying engine condition, weapons condition, systems status, navigational aids, situation awareness, a variety of radars, and in addition all the above information can be displayed regarding the wingmen's systems. Obviously, the pilot has access to a tremendous amount of information which is potentially very confusing in a combat situation.

Under the direction of Mike Patzec I reorganized some of the

formats for the displays. For example, the situation awareness format shows information about all aircraft, friendly and hostile, in a given radius. If aircraft are flying in a cluster the individual information about the aircraft becomes cluttered. Solutions that we looked at included a single value for the cluster or the displaying of information only when specifically requested. Using a Harvard Graphics computer program I then generated a visual representation of the proposed solutions which was subsequently given to the computer engineers to write into the flight simulator's program. Pilots then flew the simulators to assess and critique the effectiveness of the new formats. Because I was only with KT for two weeks, I am unaware of what the pilots thought about the displays I helped to create. Nevertheless I learned much about the steps and breadth of research studies.

RESEARCH IN FIGC

The F-16 is by design an unstable aircraft, a sacrifice made for the high maneuverability enjoyed by the fighter. An in-flight computer must make adjustments many times a second just to maintain the flight manner. The lack of stability is especially a problem at high angles of attack where the horizontal and vertical tail surfaces are blocked from the airstream by the wing. Even with the addition of two ventral fins at a 15 degree cant, the F-16 is unstable at high AOA. The USAF has recently acquired an F-16 VISTA (Variable In-Flight Stability Test Aircraft) to use as a test bed for stability and avionics research. FIGC's Design Prediction Group has as one of their many tasks to develop ventral configurations with increased stability and performance for testing on the VISTA.

William Blake designed four candidate ventral fin configurations. It was

then my job to run an aerodynamic analysis on the relative effectiveness of the fins. Several years ago McDonnel Douglas developed a computer simulation program known as MISSILE DATCOM. It worked so well that it is now a tool of almost every aerodynamic engineer. A lengthy FORTRAN program, MISSILE DATCOM can produce wind tunnel data including interference effects at a fraction of the cost and time. It was this program that I used in my analysis. The parameters for the F-16 and fins had to be determined and fed into the program which then generated the coefficients and moments associated with aerodynamics.

After the initial number crunching, I plotted the results against each other and the original configuration. Deiter Mullthop gave me the performance and stability they wanted and I found the fin among the candidates that provided results close to the desired levels. I also found that by increasing the cant to a 45 degree angle, longitudinal and directional stability could be increased without increasing the area of the fin. Although a fin was found that met the criteria and a method for further improving the performance level was developed, it is doubtful that the new configuration will see flight test due to budget cuts and a lack of funds. That does not, however, decrease the value of the tools and lessons I learned while with FIGC.

RESEARCH IN FIGD

FIGD houses the full scale simulators of the Flight Dynamics Laboratories. The simulators are indispensable in research and development as all the actual testing of ideas can be done prior to their implementation. I worked with Ralph Korthauer of the Software Design Group and was responsible for the graphics utilized by the simulators. Because I first had to become familiar with the C computer language and the UNIX VI editor, I spent four weeks in FIGD. FIGD uses

Silicon Graphics computers for the simulation graphics and a mainframe for the performance. Approxiametly fourteen different computers must be networked for a single simulation, and each is expected to function reliably. I assisted in the development of the driver program for the high resolution target model, in this case a MIG29. Ralph Korthauer had been writing the program for a month prior to my stay at FIGD and we were able to finish it and see the results on my final day of work. Not only did I acquire programming knowledge but I learned about the techniques and frustrations associated with debugging a complex computer program.

CONCLUSION

I would once again like to thank the Air Force Office of Scientific Research and Universal Energy Systems for creating and making it possible for me to participate in the Summer Apprenticeship Program. Without a doubt it has been the greatest experience of my life. The simple volume of what I learned makes my apprenticeship successful and when coupled with the headstart I have been given it makes it invaluable. I want to attend the Air Force Academy and major in astronautical engineering next year and am certain my summer apprenticeship will give me an edge in the process. Regardless, I have also learned to think for myself and different approaches towards problem solving. I also look forward to school because of the chance to learn things that obviously have a practical application. I will forever be indebted to UES and the AFOSR for the doors they have opened in my future. Thank-you!

GEOPHYSICS LABORATORY

Determining Tropical Storm Direction Of Movement Using SSM/I Brightness Temperature Data

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8/28/90

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1.0 BACKGROUND AND INTRODUCTION

On June 19,1987 the Air Force successfully launched a DMSP (Defense Meteorological Satellite Program) polar orbiting environmental satellite from Vandenberg AFB, California. The mission of DMSP is to provide global visible and infrared cloud data as well as specialized data for meteorological, oceanographic, and solar-geophysical fields, all of which are required in order to support DOD (Department of Defense) operations. DMSP data are transmitted to the AFGWC (Air Force Global Weather Central) at Offutt AFB, Nebraska, for processing and distribution.

There are 5 major sensors aboard the DMSP satellite. The OLS Operational Linescan System, the SSM/T passive microwave temperature sounder, the SSJ/4 precipitating electron spectrometer, the SSB gamma/x-ray detector, and the SSM/I Special Sensor Microwave/Imager with which this report is concerned. The SSM/I measures the dual-polarized microwave radiation from the atmosphere and surface at 4 different frequencies, 19.35, 37, 85.5, and 22.3 GHz. The first three have both horizontal and vertical polarization possibilities while the fourth measures only vertically polarized radiation. The specialty of this instrument lies in the fact that the microwave measurements of the surface are relatively insensitive to cloud cover and thus can be made under nearly all weather conditions. Due to its relatively small swath width of 1,394 km, daily coverage has gaps below the 65 degree latitude mark. Despite the gaps, the SSM/I is of great use to the Air Force because it is a good source of data for tropical cyclones. In particular SSM/I data are very helpful to the Joint Typhoon Warning Center (JTWC) because weather planes are no longer being regularly flown into typhoons in the North Pacific Ocean. The DMSP satellite that was launched on June 19, 1987 was the first weather satellite to carry this microwave sensor. During January of 1988, after the SSM/I instrument was turned back on following a 6 week shut down period, problems

started occurring with the 85V channel. During January of 1989 the instrument stopped sending any relevant data in this channel. Thus the 85V channel will not be used in this report. Two more SSM/I instruments are scheduled for launch during 1991.

This report should be considered as a preliminary investigation into the feasibility of using SSM/I brightness temperature data to predict the direction of movement of tropical cyclones.

2.0 SSM/I DATA PROCESSING

Most of the SSM/I data is not useful for studying tropical storms because the DMSP satellite is a polar orbiter and thus gathers data from around the globe. Therefore the first task is to locate the latitude and longitude of the tropical storm at a given time and compare it with the position of the satellite. When the desired data is determined it is extracted from the magnetic computer tapes and used to generate images on an RGB monitor into a mercator map. To drive the guns of the RGB computer monitor the brightness temperature data, ranging from 150K to 300K, must be converted into integers between 0 and 255. A linear conversion between brightness temperature and greyshades is used where a brightness temperature of 150K is represented by a greyshade of 255 while a brightness temperature of 300K is represented by a greyshade of 0. In order to have a central reference point that corresponded to the tropical disturbance, a point that most resembled an eye was located on the generated image using a computer program named Toggle and its screen coordinates were recorded.

With the central eye of the tropical disturbance located a FORTRAN program which determined mean and variance information could be run on the storm. This program

centered squares (boxes) of 4 different sizes (each side = 111, 222, 333, 444 km) around the eye of the storm. The box was then "cut" in half horizontally and the mean and the variance were calculated for both the upper half and the lower half. The box was then rotated clockwise one degree per "turn" over 180 degrees calculating the mean and the variance between the upper and lower rectangles for each "turn". The program calculated the angle of greatest absolute value difference between the means of the two rectangles, the angle of smallest absolute value difference between the means of the two rectangles, the angle of greatest absolute value difference between the variances of the two rectangles, and the angle of smallest absolute value difference between the variances of the two rectangles. All angles were with respect to a positive difference, defined as the upperbox having a greater value than the lowerbox (if there was a negative difference, the lowerbox having a greater value than the upperbox, then 180 degrees was added). The angles mentioned above were compared with the average angle deviation from horizontal along which the storm progressed over the next 12 hours.

4.0 RESEARCH AND RESULTS

This report consists of four sub-experiments dealing with the angles of greatest and smallest difference between the means and greatest and smallest difference between the variances as they relate to the angle of storm movement. The data set consists of two storms. Hurricane Hugo (SEP 1989) and Hurricane Gilbert (SEP 1988), with a total of seven cases, three from Hugo and four from Gilbert. From this point onward the term "55.5km box radius" will describe the square with sides equal to 111km, "111km box radius" the square with 222km sides, and so forth. In some of the graphs angles greater than 360 degrees are sometimes used. This is merely done in order to be able to run an accurate linear regression on the data. It should be noted that the total angle range of the

data should never exceed 360 degrees in any individual data set. (ranges greater than 360 would be worthless, eg. Do I choose 40 degrees or 400 degrees? Same thing but with ranges greater than 360 degrees a different angle of storm movement could be associated with each.)

4.1 RESEARCH1: ANGLE OF GREATEST DIFFERENCE BETWEEN THE MEANS

The most promising results of the report were obtained in this experiment. While the smaller box sizes (55.5 and 111 km) appear chaotic the larger box sizes (166.5 and 222 km) seem to correlate surprisingly well with the angle of storm movement. All channels except the 85H (figure 4.11) showed good results in the 222km box with R-squared values ranging from .92 to .95 (figure 4.12). The best result was obtained from the 37V channel (figure 4.13). 19V, 19H, and 22V also correlated well (R-squared $>$ .9) in the 166.5km box but all had slightly lower R-square values than in the 222km box. Averaging channels 19V, 19H, 22V, 37V, and 37H did not achieve a better correlation nor did averaging channel 22V at 222km with 22V at 166.5km (figure 4.14). It was quite evident that the better results occurred in the larger boxes. Thus when greatest difference between the means is considered, the whole storm plays a role in determining the direction rather than just the eye of the storm. Factors such as the ambient atmospheric conditions may also be influencing the data in a positive manner. It was surprising that the 85H, with its higher resolution, produced such poor results (R-squared $=$ .14 in 222km). Apparently this frequency is not very useful in determining storm direction.

4.2 RESEARCH2: ANGLE OF SMALLEST DIFFERENCE BETWEEN THE MEANS

The angle of smallest difference between the means does not appear to influence the direction of the storm nearly as strongly as the angle of greatest difference between the means. The best correlations were again in the larger boxes but only on the 22V channel (figure 4.21). In the 222km box the 22V R-squared value was .77. The smaller boxes were terrible, even the 22V did not approach significant correlation (figure 4.22).

4.3 RESEARCH3: ANGLE OF GREATEST DIFFERENCE BETWEEN THE VARIANCES

While the angle of greatest difference between the variances did not achieve the same high R-square values as the angle of greatest difference between the means the results were quite interesting. The best correlations were with the 37V, and 37H channels. The "best (dubious?)" correlation was at 222 km with the 37H channel (R-squared=.84, I label this result as "best (dubious?)" because I added 360 to 22 degrees and did not add 360 degrees to a similar angle of 55 degrees. (figure 4.31)) This experiment was especially interesting because a high R-squared value was found in the smaller box of 55.5km in channel 37V (R-squared=.82) and the data had a negative rather than a positive slope (figure 4.32). Taking the best data from the report, the angles from the channel 37V greatest mean 222km data, and subtracting from it the angles from the channel 37V greatest variance 55.5km data yields an even better correlation with the movement of the storm than either set of data alone (r-squared=.9659 compared to .9535 and .8164) or the two averaged together (figures 4.33 and 4.34). Other channels produced little correlation with storm movement (figure 4.35).

4.4 RESEARCH4: ANGLE OF SMALLEST DIFFERENCE BETWEEN THE VARIANCES

Similar to the angle of smallest difference between the means this experiment also yielded few useful results. Again, like the angle of largest difference between the variances the best results were found in the smallest box of radius 55.5km, this time at the 37H rather than the 37V channel (figure 4.4). The slope was again negative instead of positive. Little other information was gained from the smallest difference between the variances angle.

5.0 DISCUSSION AND CONCLUSIONS

5.1 COMMENTS

I found it very interesting how the best correlated greatest mean data was in the 222km box and had a positive slope while the most useful information for determining direction of storm movement in the greatest variance data was in the 55.5km box and had a negative slope. (Actually this makes sense because with mean data the storms are rarely symmetrical near the outer reaches causing greater differences between individual means. Similarly the biggest variance change would be at the storm center caused by the large difference between the warm eye and the cold intense cloud bands directly surrounding the eye.) The best results of the report were found by combining information from both the variance and the mean by subtracting the 37V variance data from the 37V mean data. In this way we were able to take the storm as a whole into account by using the mean data and take the eye into account by using the variance data.

5.2 SOURCES OF ERROR

Again, the data set in this experiment is very limited. It consisted of only two storms with a total of seven cases. If R-squared values are determined for only two points a value of one would be achieved at all times. Thus it could be possible that the high R-squared values are caused in part because we are only using two storms and thus in a way only two data points.

5.3 PROBLEMS

All of our storm angle direction data was located between 0 and 90 degrees, while the mean and variance data sometimes approached a 360 degree revolution. If the same sort of correlations arise for other quadrants methods will have to be used to determine which general area the storm is heading toward before using this method (previous storm direction history might be an option).

Will this method work for storms in the Pacific as well?

Both of the storms in our data set occurred during the month of September in the Atlantic ocean and were of the same approximate intensity. Will storms of different intensities from different months (encountering different seasonal atmospheric environments) or from different areas of the globe act differently?

This is a question which can be answered by additional research.

5.4 OVERALL

Except for the 85 channel the results obtained in this report were far better than expected. The greatest mean and variance data appear to be very useful in determining storm direction at the given time while the smallest mean and variance appear to play only a very minor role at best. Despite the fact that there was a limited amount of data, R-squared values are high enough to, in my belief, prove that there are useful correlations between the means and variances and the angle of movement. Further research should definitely be done on both the angle of greatest difference between the means and the angle of greatest difference between the variances.

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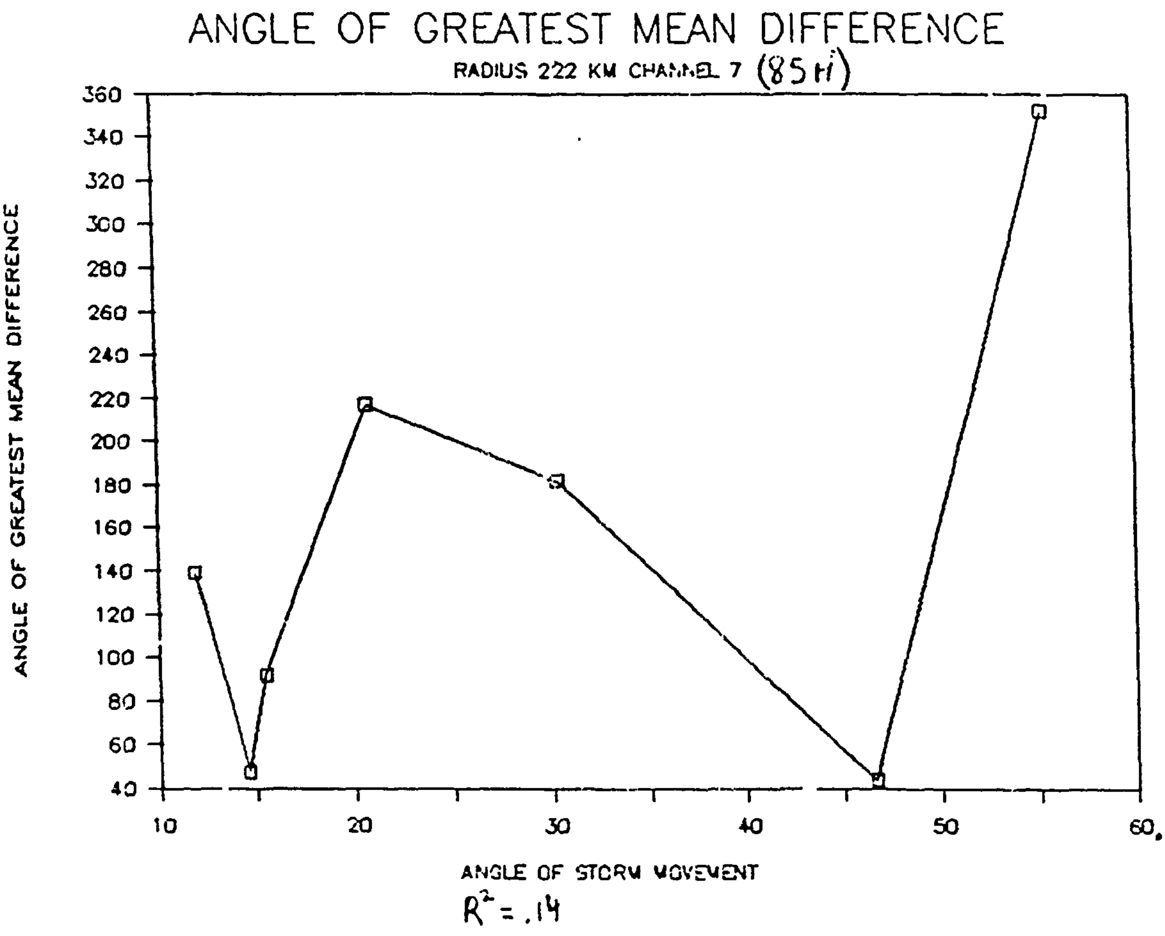
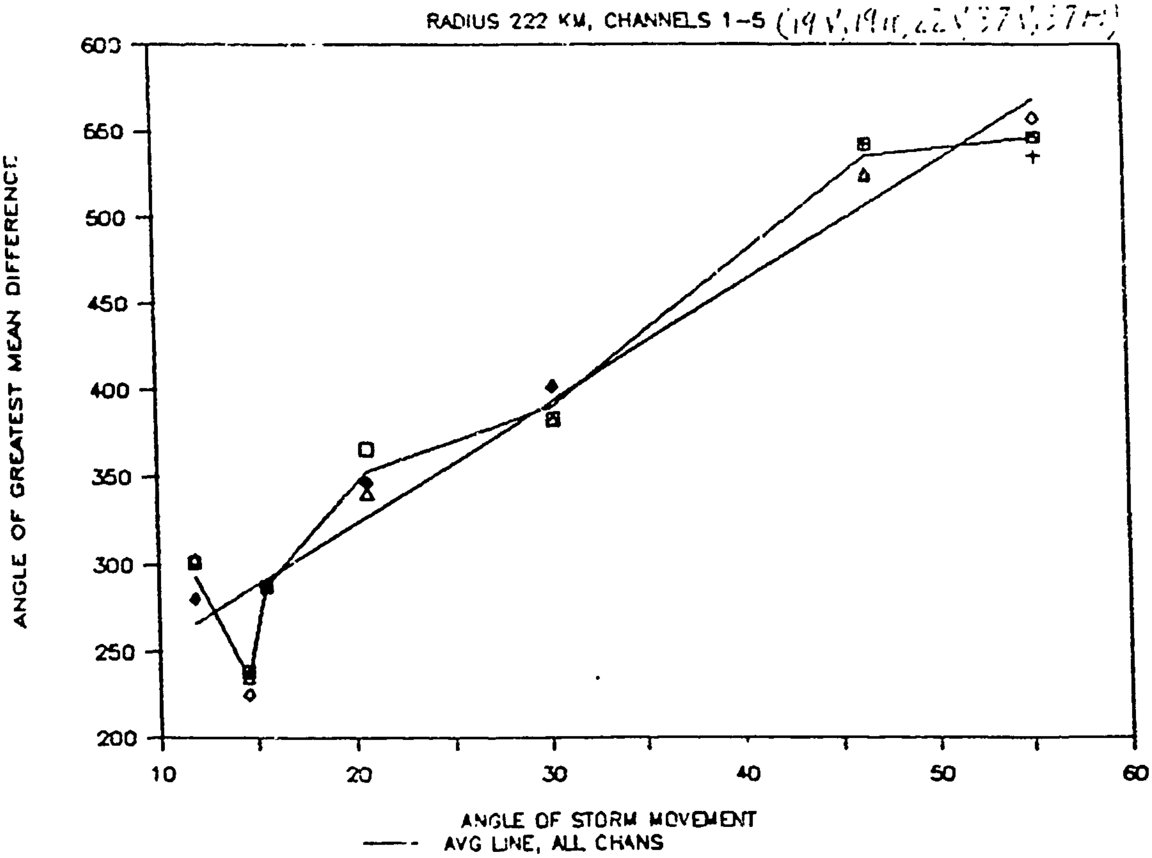
Figure (4.11)



ANGLE OF GREATEST MEAN DIFFERENCE
RADIUS 222 KM CHANNEL 7 (85H)
ANGLE OF GREATEST MEAN DIFFERENCE
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
10
20
30
40
50
60
ANGLE OF STORM MOVEMENT
$R^2 = .14$

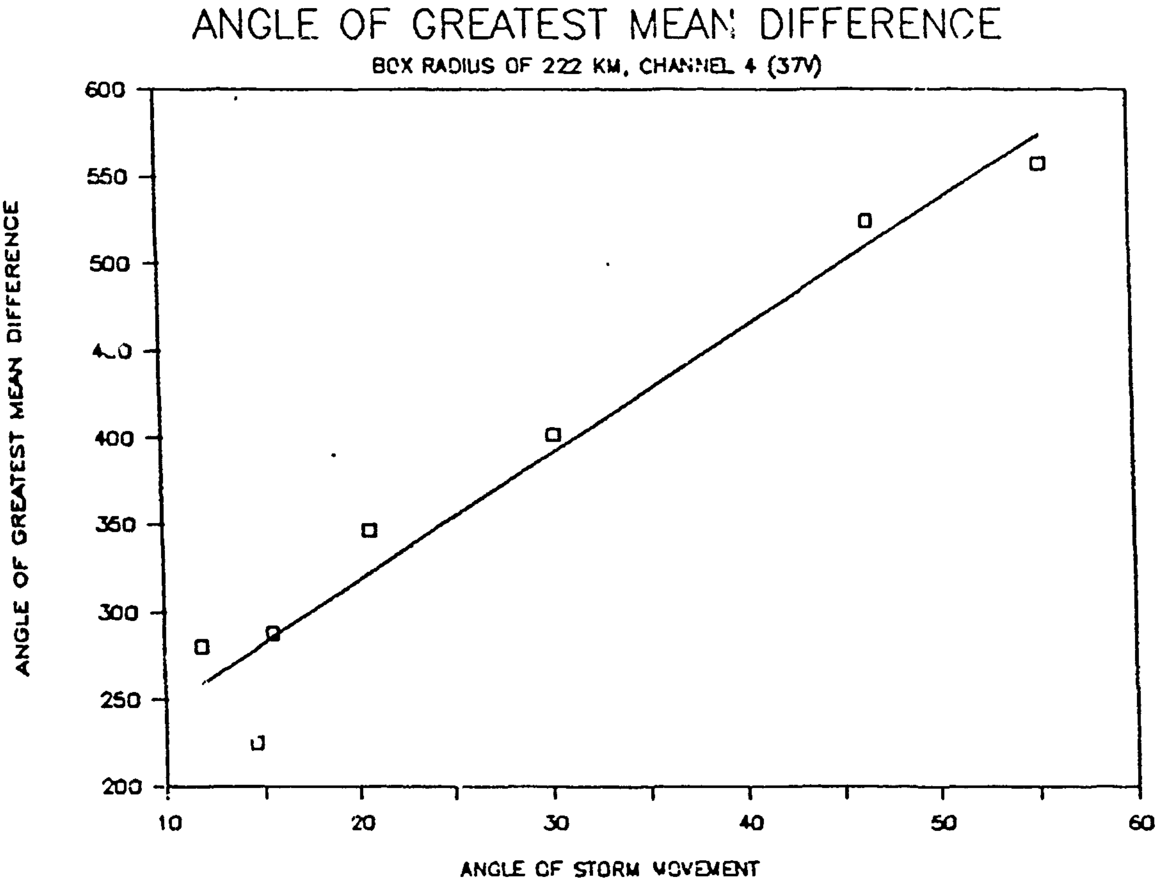
figure (4.12)

ANGLE OF GREATEST MEAN DIFFERENCE



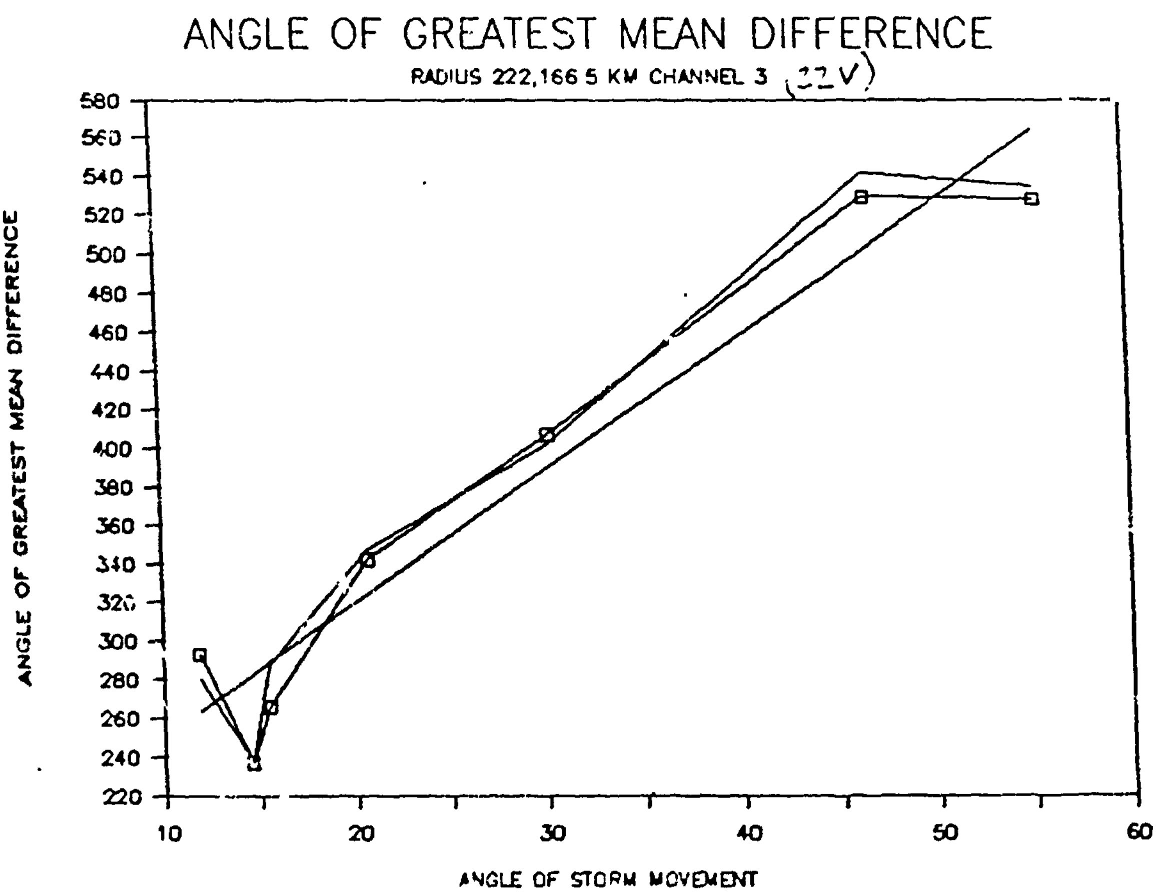
$R^2 = .942$

figure (4.13)



$R^2 = .9535$

Figure (4.14)

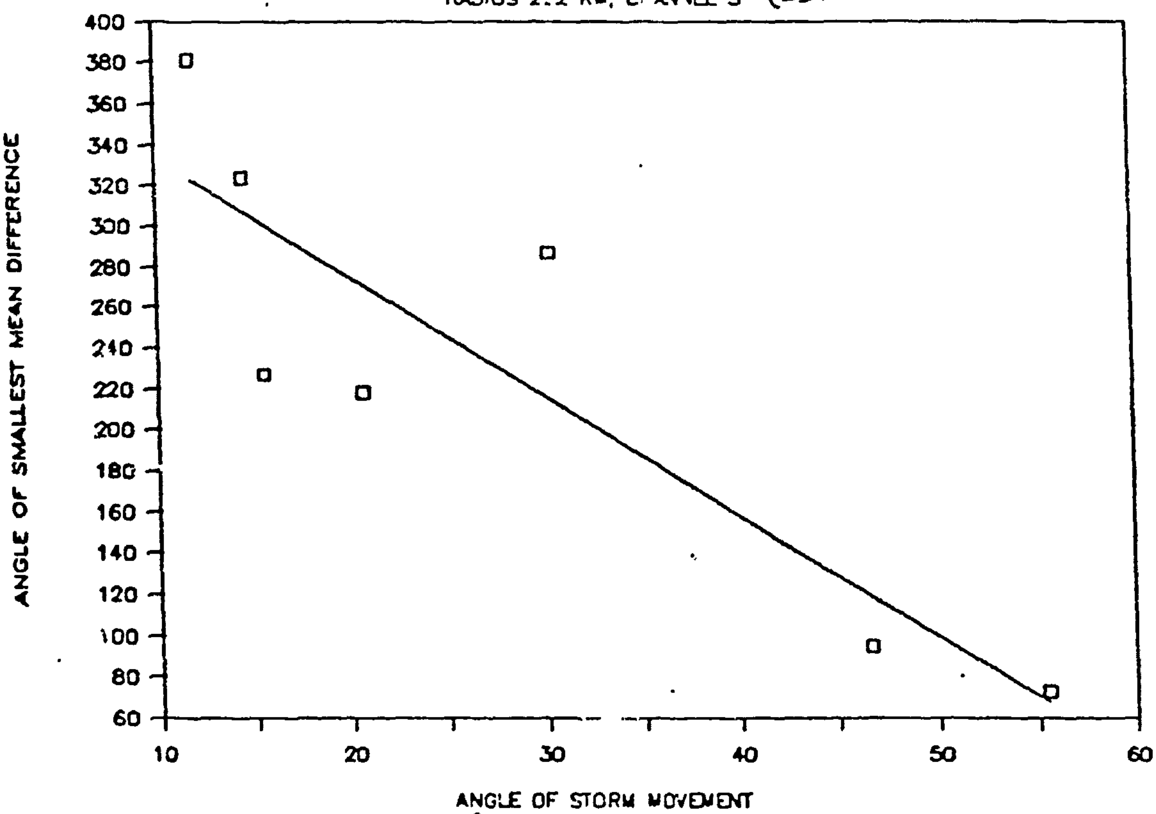


$R^2 = .939$

figure (4.21)

ANGLE OF SMALLEST MEAN DIFFERENCE

RADIUS 222 KM, CHANNEL 3 (22V)



$R^2 = .77$

figure (4.22)

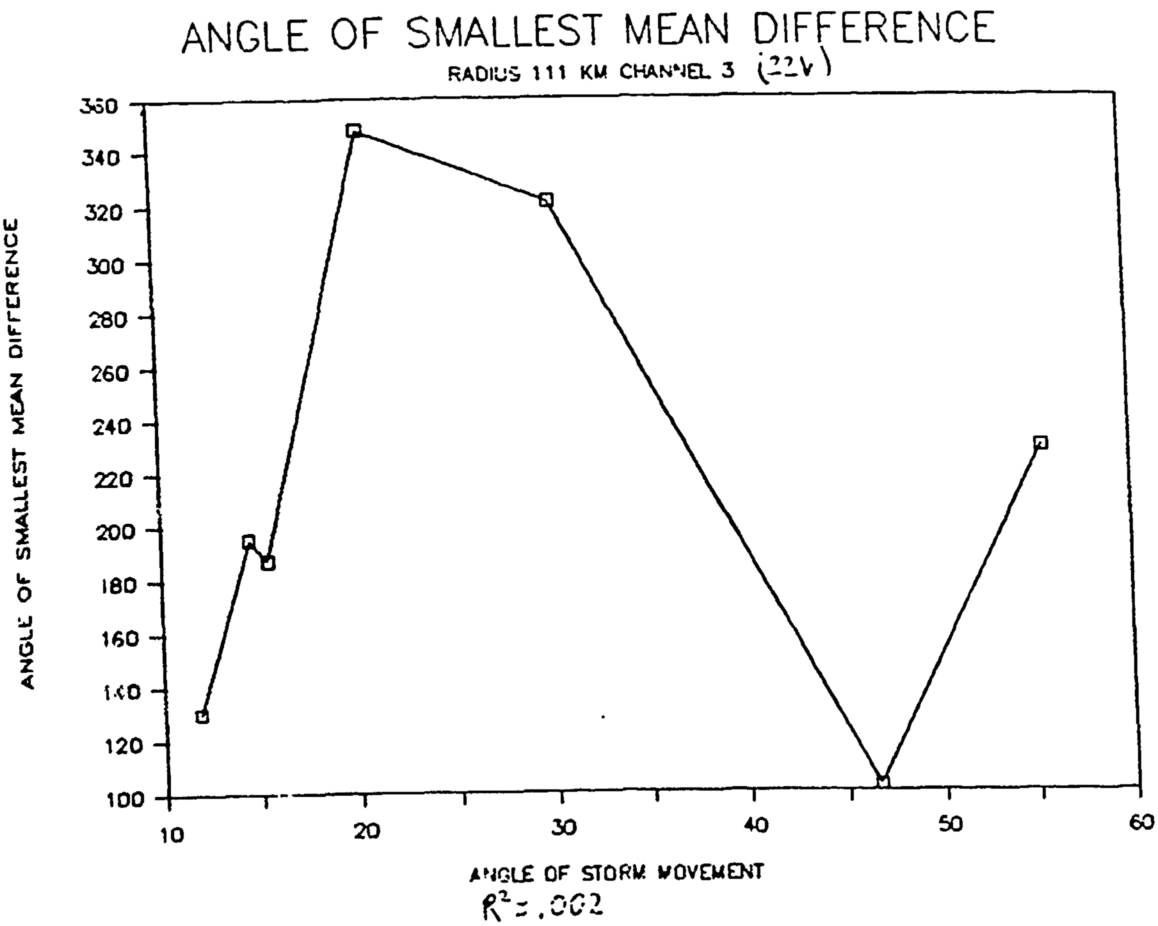
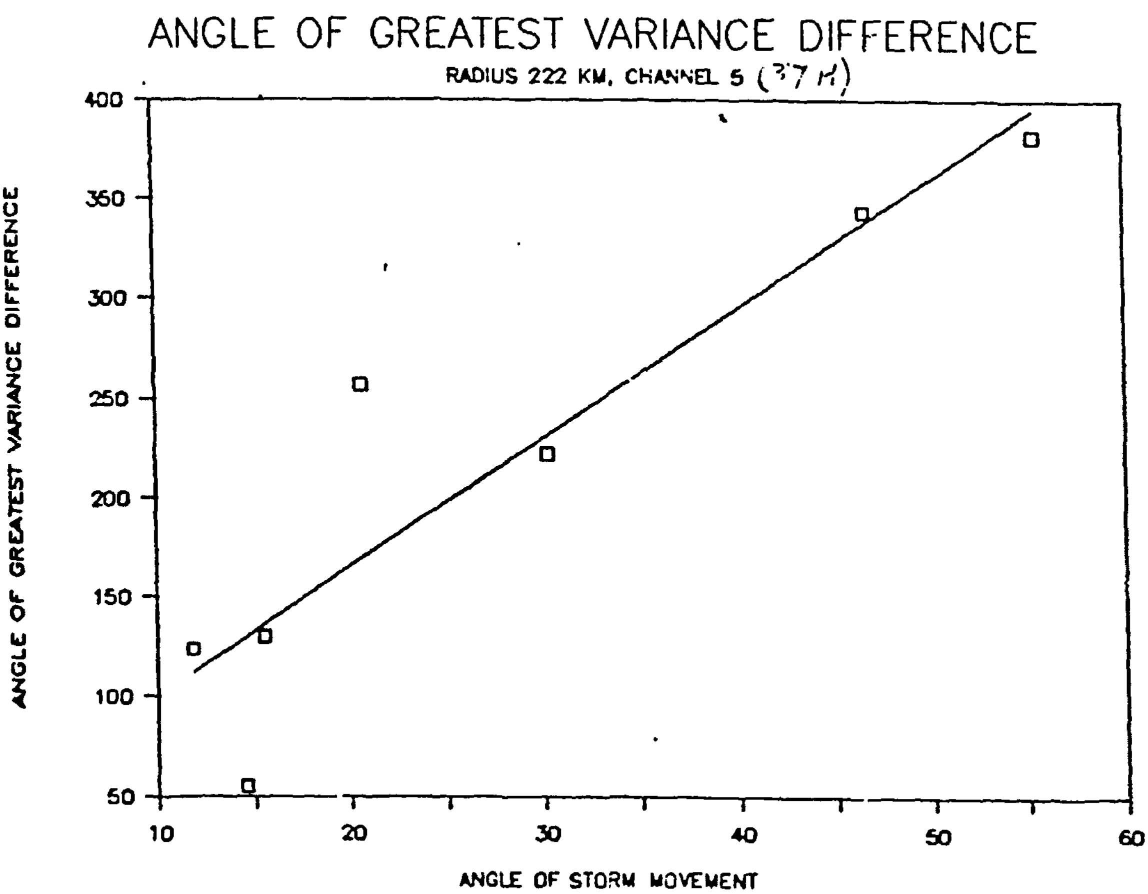
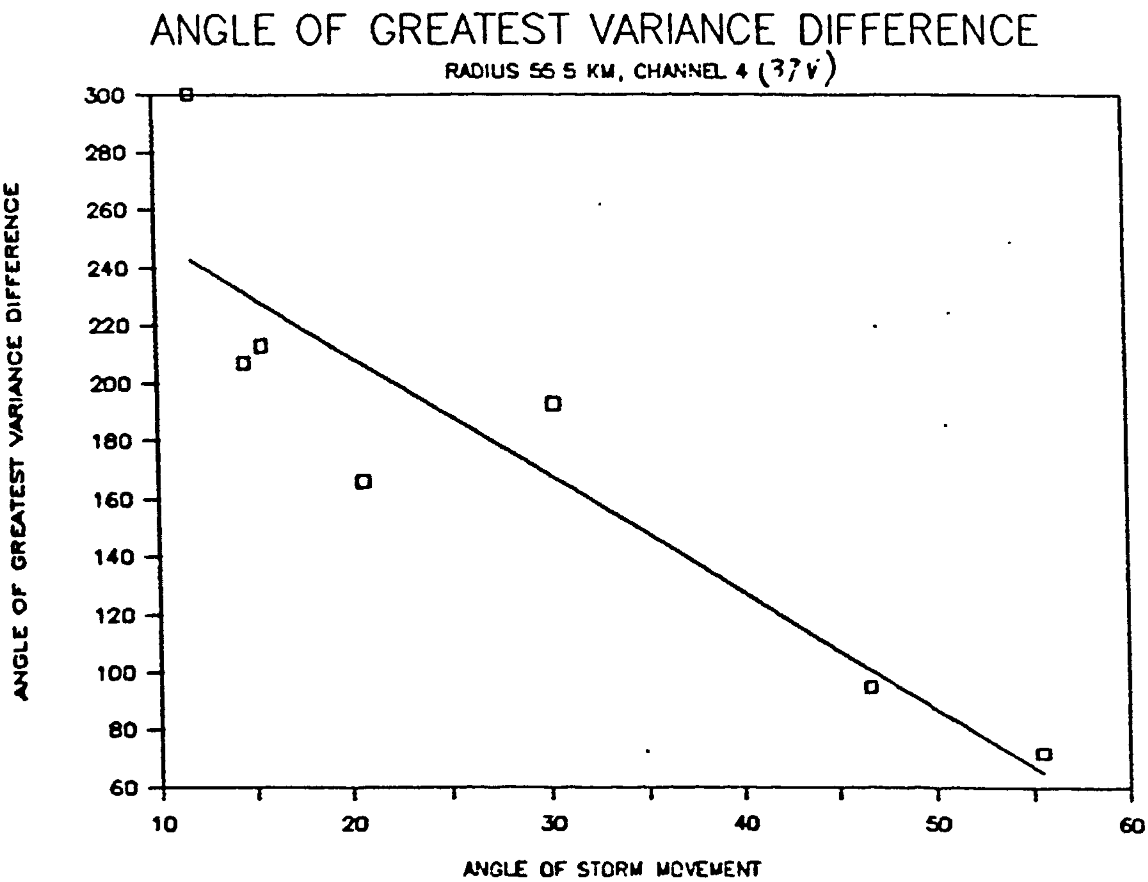

ANGLE OF SMALLEST MEAN DIFFERENCE
RADIUS 111 KM CHANNEL 3 (22V)
ANGLE OF SMALLEST MEAN DIFFERENCE
ANGLE OF STORM MOVEMENT
R^2 = .002

figure (4.31)



$R^2 = .843$

figure (4.32)

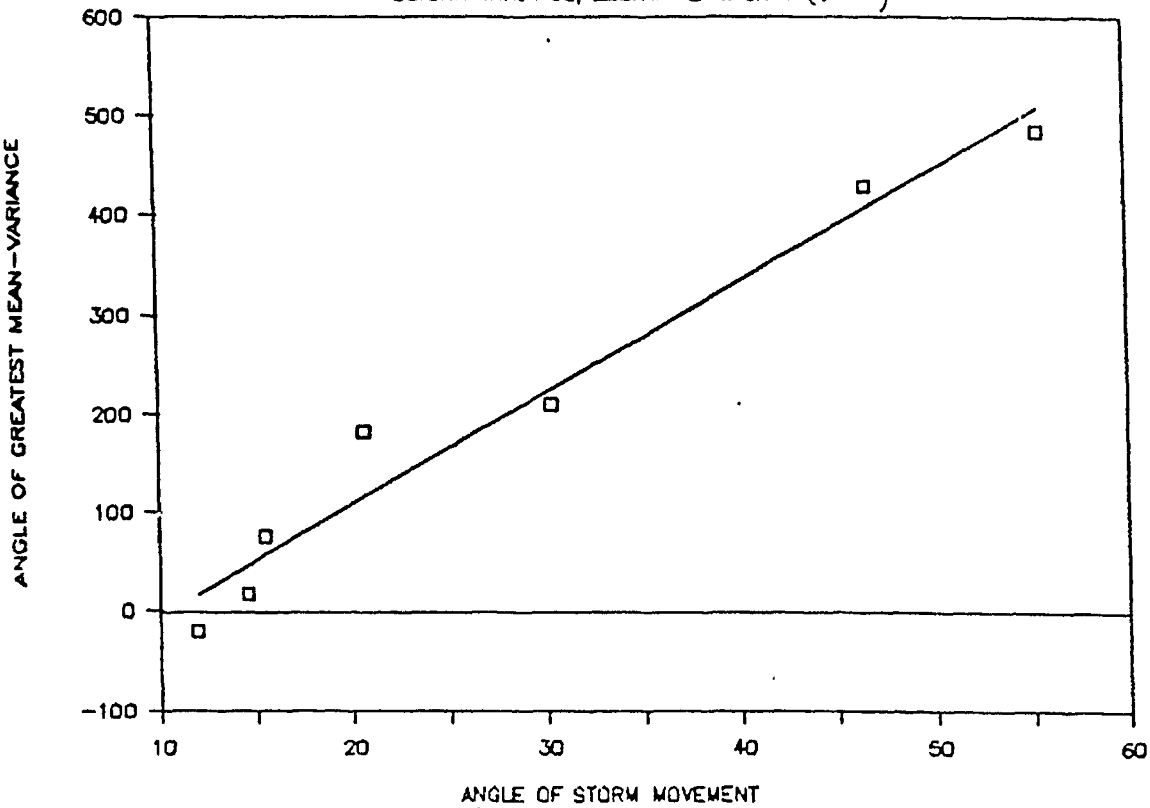


$R^2 = .816$

figure (4,33)

MEAN—VARIANCE

55.5KM VARIANCE, 222KM MEAN: CH 4 (37 V)



$R^2 = .966$

figure (4.34)

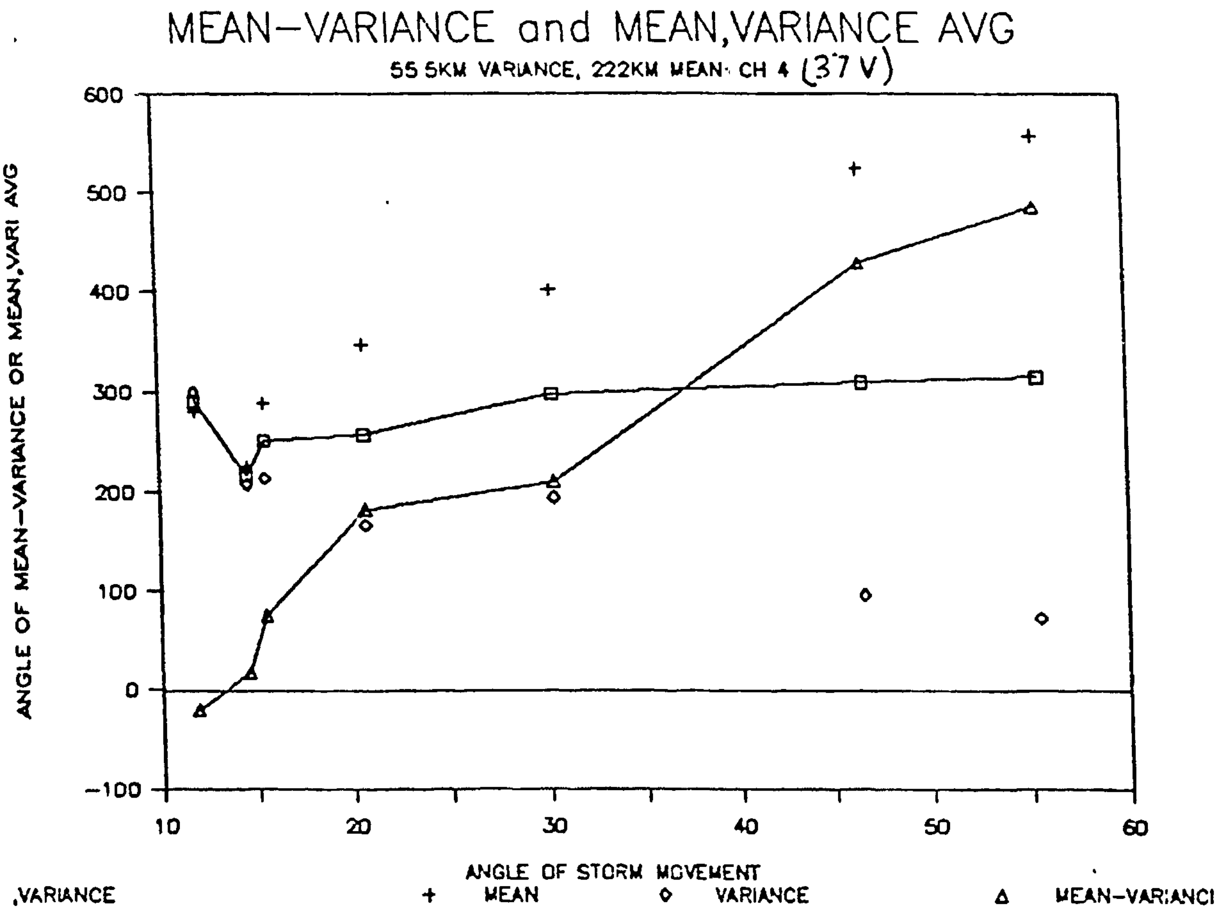
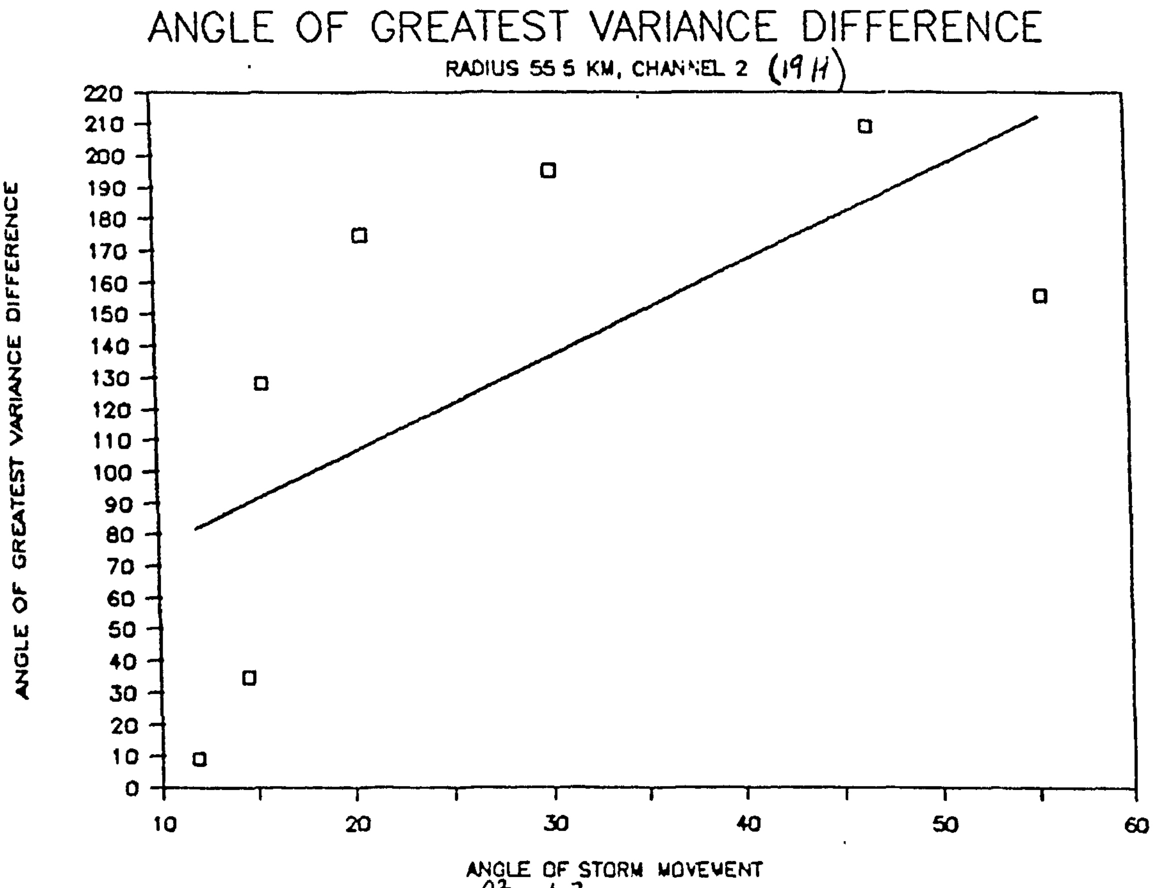

MEAN–VARIANCE and MEAN,VARIANCE AVG
55.5KM VARIANCE, 222KM MEAN: CH 4 (37 V)
600
500
400
300
200
100
0
−100
10
20
30
40
50
60
ANGLE OF MEAN–VARIANCE OR MEAN,VARI AVG
ANGLE OF STORM MOVEMENT
,VARIANCE
+ MEAN
◇ VARIANCE
△ MEAN–VARIANCI

Figure (4.35)

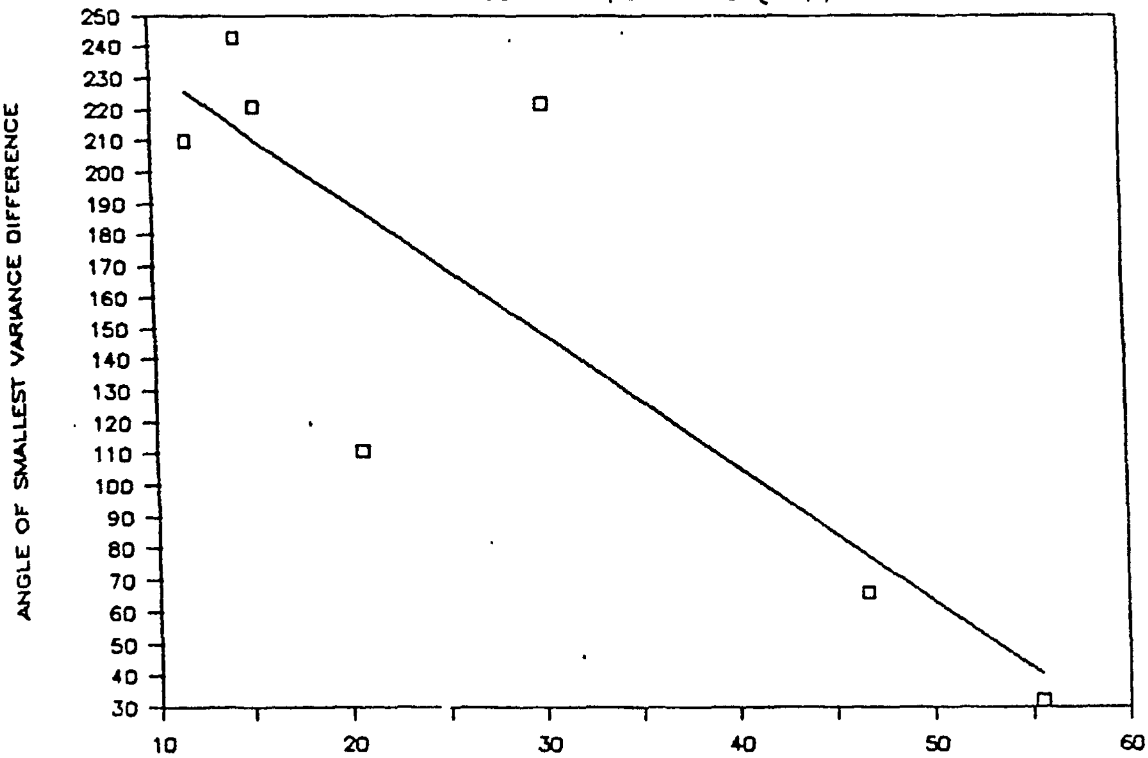


$R^2 = .43$

Figure (4.4)

ANGLE OF SMALLEST VARIANCE DIFFERENCE

RADIUS 55 5 KM, CHANNEL 5 (37H)



ANGLE OF STORM MOVEMENT

$R^2 = .71$

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Auroral Boundaries

by Weihaw Chuang
October 20, 1990
AF Geophysics Laboratory

I. **INTRODUCTION-** Why must we study the "Northern Lights"

Auroral Borealis has a significant effect on Air Force systems. Radio, radar, and even space based systems such as satellites have a vested interest in aurora research. Auroras reduces the effectiveness of medium and high frequency radio propagation in polar latitude. This reduces the capacity of radar, and communication. Auroras can be used to forecast the intensity of solar events[1] Satellites, which are damaged by these storms, can be protected, and service interruptions can be reduced. Astronauts in space stations can be informed of life threatening solar events, and take measures to protect themselves On an intellectual level, in the quest for further knowledge of our environment, auroras represent electrical phenomenon of unearthly magnitude- Power along the auroras is 10^{17} Watts, formations 3000 Km long yet only half a Kilometer wide, and physics involving highly charged particles and radiation

Physical Effect of Auroras

The ionosphere is defined as the region of the atmosphere where charged particles can reflect or absorb medium and high frequency radio. In the upper ionosphere free electrons are caused by gamma, X-ray, and ultra-violet radiation. Collisions in the lower ionosphere called the D, E, and F regions causes absorptions of radio signals passing through which are approximately 80, 100, and 200 kilometers high. Radio at a vertical incident can be reflected where the natural frequency of the plasma oscillation equals the radio frequency. This absorption is abnormally intense when auroras are active and occur because of two reasons: 1. physical reduction in propagation 2 lowering of the ionosphere. When solar activity is high and correspondingly auroral activity, the D region drops to 60 km.

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[1] Petrie William Keoeeit- The Story of the Aurora Borealis Oxford Pergamon Press 1963

Auroras are large scale electrical discharges which occur in the poleward area's of the ionosphere. The discharges are caused by solar corona interacting with upper atmosphere. Immense energies are created along the power of 10^{12} Watts is created primarily by electrons flowing downwards towards the earth along magnetic lines, and as they do so, they experience electrical potential gain on the order of few kiloelectronvolts. When the electrons collide with the atoms in lower part of the ionosphere, the atoms become excited and emit a photon much like neon lights. Because of this a curtain like apparition forms in a circular pattern around the magnetic poles along magnetic lines at approximately 67º to 59º. The formations are referred to as "auroral ovals". During intense magnetic storms the the circle can expand past the U.S.-Canadian border (59º).

Strategic Significance of Auroras

Auroras occur in a sensitive area. Since they can block radar transmission, early warning radars range and sensitivity can be reduced. For example the Over The Horizon (OTH) Radar operated in Maine uses radar which is bounced of the ionosphere to detect strategic bombers. This previously wasn't possible because the ionospheric motion was too chaotic to allowing accurate "bounces." But with the advent of three adaptive technologies, *detections and prediction* of changing ionospheric conditions, computer processing, and phased array radar, was OTH fielded. Since auroras are directly related to the intensity of solar storms, they provide a convenient method of finding the strength of these storms. Just recently it was found that the national power grid can be affected by large solar storms. These storms create potentials of hundred of voltages and dangerous current drain which black out swaths of the United States.

II. Internship

Dr Bill Swider, my mentor wanted me to find the threshold data for boundaries of the auroras The data and graphs from my work done will be collect and grouped into part of a larger study

The data comes from the Defense Meteorological Satellite Program (DMSP) which is then processed by a CDC Cyber computer The output consisted of: Geographical information- year, the day in terms of year not months (i e June 1 would by day 152), Greenwich time in seconds, the geographical latitude and longitude, the magnetic latitude and longitude which differs from geographical latitude because magnetic pole is offset by 20º fr m the true poles, and the magnetic time in seconds; and Charged Particle count- The integral of the electron count of instruments 1 to 10 representing the lower energy electrons, and that of instruments 11 to 20 representing the higher energy electrons, the integral of the ion (which are mostly H^+) count of instruments 1 to 10 like wise representing the lower energy ions, and that of instruments 11 to 20.

The classification of auroras is divided into four parts (see illustration #1). First either it can be the Aurora Borealis in the northern hemisphere, or the Aurora Australis in the southern hemisphere Then depending on the movement of the DMSP satellite, the aurora can divided into the dusk when the satellite is moving into the aurora, and dawn when the satellite is moving from the aurora to the equator Data from the equatorial boundary, especially its position is then used to make a graph showing the intensity of the aurora

Manual Series

In the earlier part of summer I accomplished searching and collating data manually from data from the DMSP satellites series. This meant that I took computer output of three to five days, about 50 pages worth, and looked for data

that met certain conditions Whenever it is dawn or dusk and when the integral of electron counts on instruments 1-10 went above 5 on the equatorwards boundary (i e I tried to find the first number above 5 on the dusk and the last number above 5 on the dawn count) I record down the data an a record sheet (see reference 1) at that point This is somewhat arbitrary, but it has basis on the fact that 5 is about 10 times above background noise which is 3 to 5. Also this system has precedence since Gussenhoven et al. (1983)[2] used a similar procedure to find evening auroral boundaries by directional integral flux set arbitrary at 10^7 In the this run I only used the northern hemisphere data since they tended to be identical with the southern Later, on the records sheet, under "comments" I added the rate the electron count change

To aid in finding the sharpness of the boundaries, I created several algorithms. All of the programs for the PC computer that I was working on was written on Turbo Pascal version 3 1, which was a hindrance since I didn't know PC Dos or PC style Pascal. The first program was "1FindTim.Pas" was used initially for the first week This program converted time in seconds to hours and minutes. Then I combined an advanced version of algorithm #1 and a program to make comments about the sharpness of the boundaries by which evolved Algorithm #2. This program is '2FindTim.Pas." See the print out in the appendix. By this time the paper work involved with making the charts was an inconvenience. Coupled with the knowledge that ultimately I was going to graph the data, I decided to store the data on the computer. Thus "3FindTim.Pas" was made with an editor so that I could store, retrieve, modify, and output the data. All the while, I was trying to create the computer programs with "ergonomics" in mind For example to make the "Dawn" vs "Dusk" command keys, I placed them on '1' and '3' respectively

[2] Gussenhoven, M.S , et al. "Systematics of the Equatorward Diffuse Auroral Boundary" Journal of Geophysics Research, Vol 88 No A7, pg 5692-5708, July 1 1983

since they are resistant to inadvertent strikes Yet this system allows me to enter in data faster than using alphanumeric commands

Automatic Series

At this point I decided to find out how to automate the entire process When I learned how to program elemental Fortran, and the CDC Cyber NOS operating system, I wrote a conversion program and a path to transfer the data from the Cyber to PC computer Modifying the program that unpacked the data on Cyber called "WeBills" so that the format can be read by a program on the PC, I then transferred the data to the PC with a program called "Connect." A program I wrote called "Bound3" on the PC side converts the ASCII data to "QuatroPro" data (a spreadsheet) also finds the boundary data. Then I use "QuatroPro" to create the graphs which are submitted to Dr Swider.

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Cyber: NOS	> Route, WETEMP, DC=TO, TIC=C, UJN=**18Sp89**	run a batch job with WETEMP The **Bold** is a 7 character file name you choose
Cyber: NOS	> EN/UJN	to see WETEMP status

How to transfer data through connect to DOS.

Cyber: NOS	Alt-F10	go to Connect Menu
PC: Connect	Selection> 4	Receive File from CYBER
PC: Connect: Receive	Micro file name: C:\Auroral\WEAAA	path and name of DOS file
PC: Connect: Receive	Host file name: WEAAA	CYBER file name
PC: Connect: Receive	Type of transfer: 1	ASCII transfer
PC: Connect	Selection> 2	go to CYBER

How to exit NOS and go to DOS:

Cyber: NOS	> Bye	
PC: Connect	Alt-F10	get to Connect Menu
PC: Connect	Selection> 9	go to DOS

BOUND3 Notes: In the current program, BOUND3 can process files with the name "WEAAA", "WEAAB", "WEAAC", and "WEAAD" and the output will be in if processing for file

North, Evening	NorEven.Dat
North, Morning	NorMorn.Dat
South, Evening	SouEven.Dat
South, Morning	SouMorn.Dat

Also type in the date so the header on the output file will have an identifying date.

How to run Bound3- the information on the date will be placed in the processed file's title.

PC: Bound3	C:\Auroral\> Bound3	
PC: Bound3	Month 12	enter month (in #).
PC: Bound3	Day 1	enter day
PC: Bound3	Year 1989	enter year
PC: Bound3	Which file: WEAAA	pick one of four files

How to run Quattro Pro which can create graphs. See Quattro Pro glossary.

PC:	c:\auroral\> Q	go to Quattro Pro

QUATTRO PRO Notes:
to get to main menu type "/" (the slash key)
so when the instructions say "/TIC" then type [slash], [t] for Tools, [i] for import, [c] for comma delimited files.

How to import a file into Quattro with the right formatting.

PC: Quattro	/FO	open a file (format)
PC: Quattro	Example1.1	
PC: Quattro	/EE	Erase the file
PC: Quattro	/TIC	Import an ASCII file

Glossary:

NOS Commands:

Command	Parameters	Comments
GET, n	n= filename	retrieves a file from "Direct Access"
ROUT n, DC=TO, TID=C, UJN=ß	n= batch program ß= user defined identification	runs a batch job
QGet, n	n= filename	"delete" a wait queue file
Purge,n	n= filename	deletes a "direct access file"

XEDIT Commands

Command	Parameters	Comments
N#[1]	# of lines	moves the cursor # of lines
P#	# of lines	lists # of lines
D		delete the preceding line
M	Once in the modify mode: #- deletes the letter above it A- replaces the character above it	modify a line
E,n,srl	n- file name (leave blank to keep the old name) s- save the newly written program r- replace the old version with current l- make the program local	to exit and save
STOP		emergency exit with no save

[1]example is N10 moves down the document 10 lines; N-2 moves up the document two lines

QuattroPro Commands

/TIC	T- tools, I- import, C- Comma delineated file	import files
/EE	E- edit, E- erase block	erase a section of data
/G[2]	Graph	go into graph menu
/PB[3]S	P- print, B- define block, S- print spreadsheet	print a portion of the spreadsheet
/PGG	P- print, G- Graph, G- go	print graph

[2]You then have to set up S[3]- series for the data, T-text for titles, X- x axis, and Y- y axis,
[3]you must outline the area by type "..'' at one corner [enter] at the opposite

Reference #1

"JUN87 F7 Data"

7-3-1990

①

	MORNING									EVENING								
Universal Time	Clat	Clong	Mlat	Mlong	MLT	E(I-W)	Comments			Universal Time	Clat	Clong	Mlat	Mlong	MLT	E(I-W)	Comments	
June 1, 1987																		
702	70.2	119.1	64.1	188.6	8:29	5.6	m=0.30		Sharp	1562	58.2	334.4	60.8	57.5	0:07	40.7	m=2.66		Sharp
6817	71.2	92.9	65.6	166.0	8:40	6.5	m=0.37	No Boundary		7702	50.9	302.5	60.0	25.8	5:02	16.2	m=1.00		Sharp
12907	71.3	62.4	66.9	144.2	8:41	10.5	m=0.54		Sharp	13852	51.9	278.2	63.7	350.5	4:28	22.5	m=1.40		Sharp
18987	72.3	41.3	67.7	133.6	8:45	6.6	m=0.34		Sharp	[illegible]5367	55.6	256.0	65.2	315.4	3:22	5.7	m=0.37		Sharp
25051	71.2	17.3	68.0	104.8	9:04	18.2	m=1.27		Sharp	25912	56.1	232.6	62.7	285.1	3:06	7.3	m=-0.41		Sharp
31119	70.1	352.7	69.4	85.9	8:46	20.4	m=1.04		Sharp	31837	66.8	214.2	67.1	261.4	3:08	6.9	m=-0.44		Sharp
37162	67.7	321.9	70.8	64.7	8:33	5.3	m=0.20		Sharp	37882	67.1	190.8	65.5	243.0	3:26	18.9	m=-1.24		Sharp
43132	61.4	309.6	68.7	39.0	8:38	11.6	m=0.55		Sharp	43942	69.5	165.0	63.7	224.1	22:05	43.9	m=-2.90		Sharp
49132	56.6	287.9	67.1	6.1	9:05	13.2	m=0.83		Sharp	50017	70.6	140.8	64.2	206.0	20:44	6.2	m=0.79		Sharp
55177	54.5	269.7	65.9	338.6	8:21	46	m=0.19		No Boundary	56077	71.6	117.6	65.4	187.0	23:19	48.7	m=3.03		Sharp
61402	62.3	235.4	67.4	286.4	7:29	6.2	m=0.32		Sharp	62182	70.4	91.3	64.8	164.5	23:40	66.4	m=4.37	Very	Sharp
67567	67.1	206.3	65.9	254.8	7:20	5.8	m=0.18	Not	Sharp, Too Far East	68302	68.8	63.8	63.8	139.8	23:52	10.5	m=-0.65		Sharp
73717	70.7	175.6	65.7	230.4	7:23	22.4	m=1.18		Sharp, Too Far East	74497	68.6	37.8	64.3	118.2	0:06	23.7	m=1.38		Sharp
79452	74.5	141.6	68.1	309.1	7:20	14.4	m=0.85	Not	Sharp "bad"	80497	67.6	10.4	64.9	96.4	0:21	15.0	m=0.95		Sharp
8[illegible]57	73.9	117.6	67.7	166.3	7:59	1.1	m=0.31		Sharp										
June 2, 1987										302	61.6	338.8	62.8	67.6	0:18	[illegible]	m=15.53	Very	Sharp "[illegible]"
5582	71.2	97.8	65.4	170.2	8:36	14.1	m=0.72		Sharp, "Good"	6457	55.1	308.5	62.7	35.9	23:54	47.4	m=-3.02	Very	Sharp "[illegible]"
11617	71.6	72.7	66.3	148.5	8:41	5.0	m=0.10	No Boundary, "Good"		12592	53.6	354.3	65.1	339.7	22:59	7.4	m=-0.33		Sharp "[illegible]"
17767	72.2	46.6	67.4	127.6	8:43	5.9	m=0.28	No Boundary, "Good"		18682	53.2	259.6	63.6	321.2	21:50	59.6	m=-3.68	Very	Sharp "[illegible]"
23847	71.9	31.4	68.4	108.5	8:59	5.2	m=0.05	Not	Sharp	24662	58.0	237.6	63.8	290.6	21:21	72.9	m=-4.78	Very	Sharp
29855	68.4	.6	66.5	81.7	9:31	4.6	m=0.23	No Boundary		30632	62.9	215.7	63.6	265.8	21:19	17.6	m=-1.14		Sharp
35902	66.2	356.9	66.0	61.2	9:37	6.3	m=0.33	Not	Sharp	36697	66.7	193.3	63.5	249.6	21:35	11.5	m=0.65	Not	Sharp
41917	62.2	314.1	68.5	44.6	9:36	5.3	m=0.07	Not	Sharp	42660	71.8	174.1	66.5	228.3	22:03	46.1	m=-2.91		Sharp
47877	60.6	290.3	71.3	11.1	9:00	10.3	m=0.63	Not	Sharp	48722	73.7	151.5	67.4	211.7	22:42	14.7	m=-1.24		Sharp
54052	60.0	266.3	70.9	329.6	8:12	6.0	m=0.26		Sharp	54803	72.9	127.0	67.5	193.7	23:22	11.2	m=-0.73	Not	Sharp
60232	65.4	237.7	70.6	285.0	7:00	5.4	m=0.38	Not	Sharp	60877	74.1	103.4	68.1	174.8	23:57	12.9	m=-0.83		Sharp
66443	72.3	207.9	70.8	247.1	6:29	10.6	m=0.62		Sharp	66987	73.1	76.3	67.6	152.3	0:49	51.7	m=-2.72		Sharp
72607	76.3	167.5	70.9	219.2	6:21	7.2	m=0.35		Sharp	73097	72.4	48.0	67.5	127.6	0:31	46.3	m=-3.16	Very	Sharp
78697	76.5	141.0	70.1	201.8	6:51	5.1	m=0.33		Sharp	79752	68.4	16.6	65.3	101.7	0:30	1.2	m=0.44		Sharp
84772	75.9	117.2	69.6	165.1	7:33	11.4	m=1.26		Sharp, "Too Far East"	85367	65.6	347.4	65.7	77.5	0:34	6.1	m=-0.35	Not	Sharp "[illegible]"
June 3, 1987																			
4432	74.8	95.5	68.6	168.4	8:12	8.3	m=0.53	Not	Sharp "bad"	5107	63.3	3.78	68.4	51.7	0:36	19.0	m=-1.19		Sharp "Too [illegible]"
10473	73.8	73.6	68.2	150.2	8:32	7.1	m=0.32		Sharp	11372	55.5	331.3	69.3	13.7	23:33	22.1	m=-1.27		Sharp
16507	73.5	49.0	68.7	130.6	8:28	5.7	m=0.11	Not	Sharp	17377	57.2	266.7	68.4	331.1	22:11	6.9	m=-0.44		Sharp
22732	77.2	11.5	74.5	110.3	8:46	8.1	m=0.35		Sharp "Too [illegible]"	23392	61.1	344.7	68.4	94.2	21:36	5.8	m=0.31		Sharp
28792	76.4	347.1	75.7	94.2	9:21	11.3	m=0.05		Sharp	27357	65.9	273.7	63.2	320.3	21:16	25.5	m=-2.35		Sharp

Reference #1a

"JUN87 F7 Data"

7-3-1990

(2)

MORNING

Universal Time	Clat	Clong	Mlat	Mlong	MLT	E(0-10)	Comments	
34???	70.0	348.9	71.7	73.8	9:36	6.9	m=0.15	Not Sharp
40783	67.7	315.9	73.8	49.3	9:36	8.2	m=0.43	Sharp
46762	61.4	294.0	71.4	18.2	9:13	10.2	m=0.37	Sharp
52177	52.6	323.6	69.0	341.0	8:24	6.4	m=0.30	Sharp
58932	61.3	346.0	68.5	298.2	2:37	12.3	m=0.51	Sharp
65197	71.5	310.4	71.0	262.9	6:29	10.9	m=0.48	Sharp
71332	74.2	179.3	69.6	328.9	6:40	10.5	m=0.48	Sharp
77432	75.2	158.3	69.0	308.4	7:00	15.4	m=0.80	Sharp
83512	24.6	186.0	68.2	182.4	7:40	8.8	m=0.55	Sharp
June 4, 1987								
3247	76.9	94.3	70.2	167.6	7:46	8.1	m=0.59	Sharp
9377	77.3	68.3	71.5	148.2	8:07	7.3	m=0.33	Sharp
15382	75.2	48.8	70.2	132.5	8:29	5.0	m=0.09	Not Sharp
21503	77.5	17.2	74.0	113.8	8:43	9.0	m=0.39	Sharp
27517	74.3	0.4	72.7	97.2	9:10	5.1	m=0.12	Sharp
33502	69.3	343.4	70.0	77.9	9:22	8.6	m=0.31	Not Sharp
39508	64.8	320.3	69.3	55.3	9:29	5.9	m=0.25	No Boundary
45472	58.3	301.9	67.3	27.3	9:22	5.9	m=0.09	Sharp
51517	56.0	278.6	67.7	350.9	8:50	9.3	m=0.33	Not Sharp
57497	61.2	250.9	69.7	305.2	7:40	12.2	m=0.54	Sharp
63862	65.9	222.6	68.0	269.3	7:10	8.5	m=0.45	Not Sharp
70013	69.5	192.5	66.6	247.6	7:13	8.3	m=0.39	Not Sharp
76177	73.9	159.2	67.9	216.5	7:08	16.7	m=1.01	Sharp
82291	75.2	75.3	68.9	184.4	7:36	9.2	m=0.56	Sharp
June 5, 1987								
1987	75.5	103.6	69.3	174.8	7:56	5.3	m=0.23	Not Sharp
8037	73.7	83.5	67.9	158.3	8:26	7.5	m=0.18	No Boundary
14112	74.9	58.0	69.0	138.0	8:03	13.7	m=0.67	Not Sharp
20192	71.7	37.4	67.4	00.2	8:48	6.8	m=0.35	Sharp
26202	70.6	13.2	67.7	101.2	9:07	8.8	m=0.37	Not Sharp
32302	70.8	346.3	71.1	82.1	9:29	9.9	m=0.61	Sharp
38362	69.3	320.1	73.7	39.1	9:38	10.4	m=1.41	Sharp
44317	62.3	304.0	70.7	32.3	9:26	5.0	m=0.07	Not Sharp
50322	56.8	283.0	68.2	355.3	8:57	5.6	m=0.17	No Boundary
56402	55.7	257.5	68.5	316.3	8:01	7.1	m=0.24	Not Sharp
62542	61.0	231.6	65.3	282.2	7:32	9.5	m=0.36	Sharp
68787	69.7	198.1	67.2	246.4	7:07	8.6	m=0.27	No Boundary
74917	75.2	161.3	69.4	216.5	6:48	8.1	m=0.1	Sharp

EVENING

Universal Time	Clat	Clong	Mlat	Mlong	MLT	E(1-10)	Comments	
35403	69.8	202.5	68.0	249.4	21:29	8.3	m=-0.55	Not Sharp
41437	70.6	180.7	68.0	231.8	21:52	19.0	m=-1.21	Sharp
47497	73.7	157.0	67.7	252.2	22:34	36.7	m=-2.29	Sharp
53587	73.2	130.6	66.8	186.7	23:10	9.5	m=0.47	Not Sharp
59632	74.9	110.1	68.6	180.1	23:55	5.1	m=-0.31	Sharp
65752	73.2	81.5	62.5	151.5	0:14	12.6	m=-1.24	Sharp
71902	70.1	50.4	65.3	131.2	0:10	8.8	m=-1.12	Sharp
78002	69.1	22.9	65.6	107.1	0:21	5.8	m=0.36	Sharp
84132	67.2	354.4	66.4	89.2	0:38	5.2	m=-0.30	Sharp
3962	64.2	325.[illegible]	68.2	56.0	0:41	21.5	m=4.62	Very Sharp
10057	57.8	296.3	67.8	18.3	23:41	41.6	m=2.74	Sharp
16177	55.7	270.7	67.1	337.8	22:21	11.1	m=-0.73	Sharp
22207	58.7	248.1	66.8	303.9	21:30	43.8	m=-29.21	Very Sharp
28327	63.4	226.6	66.6	275.3	21:18	9.1	m=0.51	Sharp
34407	68.1	205.8	67.0	253.3	21:05	52.8	m=3.55	Very Sharp
40267	69.7	181.2	65.1	234.9	21:50	35.1	m=3.65	Very Sharp
46432	70.0	133.4	63.8	312.0	22:20	16.4	m=-1.06	Sharp
52417	70.2	130.6	64.0	198.1	22:55	11.8	m=0.75	Sharp
58462	72.0	168.8	66.0	179.5	23:21	451.0	m=29.05	Very Sharp
64582	70.2	81.1	64.8	155.4	23:48	6.4	m=-0.42	Sharp
70717	67.8	52.6	63.0	129.5	23:53	7.5	m=0.49	Sharp
76702	68.4	22.2	64.6	109.8	0:11	6.2	m=0.39	Sharp
82882	68.1	.6	66.4	89.6	0:22	7.6	m=-0.33	Sharp
2677	61.9	329.0	65.1	59.4	0:22	74.2	m=3.25	Sharp
8672	55.6	299.7	65.0	23.8	23:42	26.8	m=-1.62	Sharp
14712	54.1	274.8	65.7	344.6	22:32	51.9	m=-3.77	Very Sharp
20893	57.9	252.5	66.9	302.4	21:37	10.8	m=0.46	Not Sharp
26962	64.2	232.2	68.5	280.2	21:15	17.6	m=1.14	Sharp
32977	66.3	210.9	61.8	257.2	21:20	9.0	m=-0.59	Not Sharp
39007	71.1	188.9	67.5	238.6	21:44	43.4	m=2.88	Sharp
45082	71.6	163.2	65.8	221.2	22:15	13.1	m=0.85	Sharp
51157	71.8	135.1	65.5	203.3	22:55	9.8	m=0.54	Sharp
57282	70.5	117	64.6	181.9	23:17	62.5	m=-4.07	Very Sharp
63367	69.4	85.2	64.1	158.3	23:[illegible]	17.3	m=-1.13	Sharp
69442	70.1	60.8	65.1	137.0	0:04	14.0	m=-0.07	Sharp
75560	64.4	32.7	64.3	113.7	[illegible]	9.3	m=0.7[illegible]	Sharp

Reference # 6

"JUN87 F7 Data"

7-5-1990

(3)

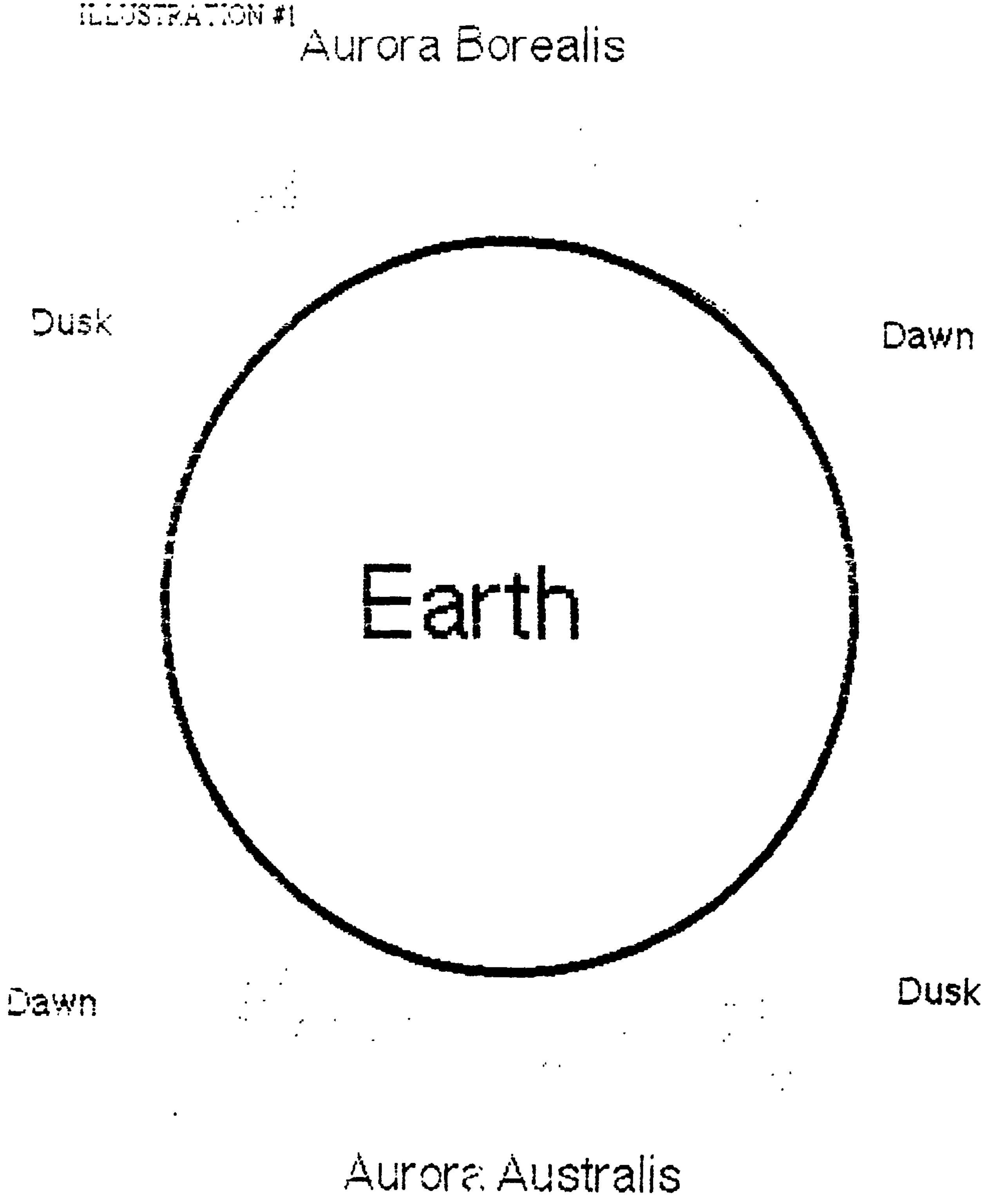
MORNING

Universal Time	Chat	Chang	Mlat	Mlong	MLT	E(1-10)	Comments	
81061	75.3	134.4	66.7	178.2	7:19	11.8	m=0.78	Sharp
JUNE 6, 1987								
712	73.4	113.8	67.1	183.5	8:05	6.6	m=0.37	Not Sharp
6817	74.4	86.9	68.5	161.3	8:21	13.4	m=0.55	Not Sharp
13901	74.8	61.2	69.5	141.0	8:28	6.1	m=0.21	Not Sharp
18161	73.9	38.1	67.4	130.5	8:40	12.4	m=0.53	Sharp
25012	72.1	15.9	69.1	104.9	9:02	6.5	m=0.21	Not Sharp
31102	72.4	348.9	72.2	86.2	9:25	23.9	m=1.53	Sharp
37042	64.8	322.5	61.3	65.0	9:37	8.8	m=0.29	Not Sharp
43012	58.5	300.0	65.3	40.1	9:35	5.6	m=0.10	No Boundary
48947	52.8	290.1	63.9	8.9	9:15	11.7	m=0.45	Sharp
55087	53.1	265.6	64.1	330.3	8:33	7.7	m=0.26	Not Sharp
61352	59.3	237.7	65.1	290.0	7:45	5.1	m=0.09	Sharp
67402	61.8	211.3	61.5	262.8	7:49	8.3	m=0.61	Sharp
73537	64.8	183.0	60.1	239.6	7:57	5.0	m=0.17	No Boundary
79717	69.7	151.0	63.4	214.1	7:59	9.6	m=0.33	Sharp
85851	71.2	122.9	65.0	191.5	8:18	7.2	m=0.34	Not Sharp
JUNE 7, 1987								
5527	71.4	97.7	65.6	170.1	8:36	9.6	m=0.43	Sharp
11647	71.3	69.7	67.9	146.8	8:34	6.0	m=0.34	Not Sharp
17772	73.1	45.0	68.3	127.2	8:40	5.4	m=0.21	Not Sharp
23797	72.9	19.8	69.4	108.4	8:56	7.4	m=0.41	Not Sharp
29837	73.1	353.1	72.4	90.2	9:22	13.5	m=0.53	Sharp
35912	70.7	330.2	73.7	70.0	9:39	6.8	m=0.35	Not Sharp
41542	61.6	314.5	61.8	45.0	9:35	5.5	m=0.09	Sharp
47352	57.6	292.5	65.1	13.5	9:02	12.2	m=0.60	Not Sharp
53812	52.2	270.9	63.8	330	8:43	5.5	m=0.21	Not Sharp
72367	67.9	165.1	63.6	238.9	7:37	6.1	m=0.25	Not Sharp
78562	70.4	155.[illegible]	64.2	216.7	7:47	11.0	m=0.41	Sharp
84637	72.7	12[illegible]	66.4	193.1	8:03	13.5	m=0.[illegible]	Sharp

EVENING

Universal Time	Chat	Chang	Mlat	Mlong	MLT	E(1-10)	Comments	
81667	67.3	5.0	65.3	92.3	0:26	65.3	m=-4.17	Very Sharp
1417	63.6	335.5	65.6	66.3	0:32	18.8	m=-.13	Sharp
7582	58.9	306.8	66.8	34.0	0:08	186.4	m=-2.18	Very Sharp
13247	54.1	277.7	66.0	352.7	22:47	52.0	m=-3.21	Very Sharp
19807	55.4	256.0	65.1	315.5	21:49	11.5	m=-0.75	Sharp
25837	58.7	233.1	63.3	285.4	21:17	5.0	m=0.31	Sharp
31897	60.4	208.7	59.7	261.6	21:30	8.6	m=-0.52	Sharp
37927	63.5	185.0	59.1	241.7	21:38	58.7	m=3.79	Very Sharp
43987	64.8	159.4	55.4	233.0	22:03	15.4	m=-0.97	Sharp
50047	65.7	135.1	59.3	203.4	22:33	8.7	m=0.43	Sharp
56092	67.5	112.3	61.7	183.3	23.03	8.0	m=-0.38	Sharp
62167	67.9	88.2	62.6	161.4	23:37	100.5	m=-6.91	Very Sharp
68302	69.5	60.2	60.6	175.4	23:4[illegible]	23.2	m=1.45	Sharp
74422	63.7	32.8	59.6	111.5	23:39	23.9	m=-1.54	Sharp
80537	62.6	5.9	60.2	82.4	23:54	58.2	m=3.04	Very Sharp
262	59.2	337.2	61.1	65.6	0:00	10.8	m=0.55	Sharp
6472	52.3	308.3	60.2	37.6	23:47	14.2	m=-0.89	Not Sharp
12592	50.1	282.8	61.9	352.1	22:58	5.2	m=-0.33	Sharp
18562	56.2	261.4	66.7	323.0	21:55	11.5	m=0.73	Sharp
24547	61.7	240.3	68.0	291.1	21:[illegible]	26.3	m=1.69	Sharp
30562	65.7	218.6	67.0	265.9	21:15	14.3	m=2.95	Sharp
36622	67.3	194.2	64.2	245.5	21:33	14.1	m=0.92	Sharp
42652	70.2	171.4	64.8	223.0	22:00	51.4	m=-3.29	Very Sharp
48742	69.7	144.8	63.3	209.5	23:32	58.6	m=-3.85	Very Sharp
67027	67.7	67.7	62.7	143.0	23:43	54.6	m=3.4[illegible]	Very Sharp
73147	66.0	40.3	61.7	118.7	23:4[illegible]	59.5	m=-3.63	Very Sharp
79167	64.2	13.[illegible]	61.3	95.5	23:5[illegible]	13.0	m=0.51	Sharp
85402	61.4	344.1	61.8	71.8	0:11	10.1	m=0.6[illegible]	Sharp

ILLUSTRATION #1



SUPPLEMENTAL INFORMATIONS

Master Menu -

C - Collect data - go to "Collect record" menu
E - Modify data - allows users to correct any mistakes, insert, or delete records
S - Save data - backups up data
L - List data - prints out the record on the screen
P - Print Data - prints out the record on the printer
Q - Quit

CREATE RECORD MENU
Diagram showing the location of commands on the numeric pad.

7	8 SAVE data	9
4	5 change DATE	6
1 collect DAWN	2	3 collect DUSK
0 RETURN to master menu		

MODIFICATION MENU
Diagram showing the location of commands on the numeric pad.

7 go to BEGINNING of records	8	9 DELETE current record
4	5 change DATE	6
1 go to END of records	2 MODIFY current record	3 INSERT new record
0 RETURN to master menu		

MANUAL PROCEDURES (June - late July)

Finding Auroral Boundaries

Operations:
How to find auroral boundaries manually using the IBM Computer to convert time and/or to store data.

These step by step instructions will allow you to run 2FindTim and 3FindTim. The instructions assume that 2FindTim and 3FindTim are on a hard-disk drive assigned C. "Manual" indicates a process to be either done by hand or mentally calculated.

PROGRAM: 2FINDTIM.EXE (created June 22, 1990)

Where	Command	Comments
PC: Dos	C:\2FINDTIM.EXE	Execute 2Findtim.exe on the PC
Manual[1]	find auroral boundary	see text for algorithm
Manual	line up ruler (see illustration 2) with data	find data accurately
Manual	copy UT[2], CLat, CLong, MLat, MLong to data sheet (see data) under either Dawn or Dawn Records	
PC. 2FindTim	1 for Dawn Data 3 for Dusk Data	helps algorithm determine positive or negative slope
PC. 2FindTim	enter MLT Data	
PC. 2FindTim	Ecurrent(1-10) Data	
PC: 2FindTim	Eprevious(1-10) Data	helps algorithm find the slope
PC 2FindTim	Efollowing(1-10) Data	helps algorithm find the slope
PC 2FindTim	if the data is accurate hit [ENTER] else 1	
Manual	read MLT in hours and seconds from the computer and write it down on the record sheet	
Manual	read and write slope	

[1] beginning of repeat loop
[2] see Chart 1

Manual	read and write comments	comments. no boundary, not sharp, sharp, very sharp
	repeat at "manual[2]" until done	

PROGRAM 3FINDTIM.EXE (created July 6, 1990)

An example of how run initually 3FindTim.

PC. DOS	C:\3FINDTIM.EXE	execute 3Findtim
PC. 3FindTim	MM Enter $: C	go to Collect Menu
PC. 3FindTim	C Enter #: 5	set date
PC. 3FindTim	ENTER #: month	type the record's date
PC. 3FindTim	Day ENTER: day	
PC. 3FindTim	Year ENTER. year	
PC: 3FindTim[3]	C Enter #: 1 / 3	enter either under dawn or dusk records
PC: 3FindTim	UTime ENTER: UT	
PC: 3FindTim	MLTime ENTER: MLT	
PC: 3FindTim	Current Elec ENTER: Ecurrent(1-10) Data	
PC. 3FindTim	Prev Elec ENTER. Eprevious(1-10) Data	
PC: 3FindTim	Next Elec ENTER: Efollowing(1-10) Data	
PC: 3FindTim	hit [ENTER] if the data is correct or 1	
	Repeat loop at "PC: 3FindTim[3]	
PC: 3FindTim	every 14 records at: C Enter #: 8	backs up record
PC: 3FindTim	change date when necessary using: C Enter #: 5	change date

See diagrams for further information or if you need to edit the record.

[3]beginning of the repeat loop

Finding Auroral Boundaries

Operations:

How to use the software on the Cyber and the PC to find auroral boundaries.

If you follow the instruction below linearly, letter for letter, you should be able to run a batch job in ten minutes. Left out are sections where you follow instructions given by the computer.

> NOS Notes: The Cyber NOS operating system has three "access" levels. The first is LOCAL ACCESS where files can be written , modified and executed. DIRECT ACCESS and INDIREC ACCESS, the other two, are where data is stored. Files can also be be stored in the "WAIT QUEUE". NOS has a time limit to how long the terminal can be left unused; this is approximately fifteen minutes.

Where	Command	Comments

How to get onto the Cyber computer. See NOS glossary.

PC	C:\Connect	executes communication software
PC:Connect	Selection> 2	go into Cyber terminal mode
PC:Connect	>> connect CDCNet	
PC:Connect	Do NOS	
Cyber: NOS	USER NAME: Heinem,Nany0	
Cyber: NOS	CHARGE NUMBER: 4418,7601	

How to get and modify program WETEMP. This will allow the user to "unpack" and sort out the data using batch files.

Cyber: NOS	> Get, WETEMP	makes WETEMP modifiable
Cyber: NOS	> Xedit, WETEMP	put WETEMP in editor mode

Mesoscale Modeling

Christopher Andrew Guild

George Modica

Hanscom Air Force Base Geophysics Laboratory

October 20, 1990

Acknowledgments:

I would like to thank George Modica for sharing his knowledge of meteorology and computer programming during my summer apprenticeship.

I would also like to thank Sergeant Joe Doherty and other employees at the Lab who helped me not only learn the extensive operating languages, but got me out of some tough programming problems.

Just eight weeks ago, I started a one month program which dealt with computer generated graphics. Forecast winds from a 3-D Numerical Weather Prediction (NWP) model were collected at one hundred different times during a six hour forecast. Then, the forecast winds were processed in such a way that animations of the time -sequences could be viewed at a special Adage-connected terminal.

Typically, output from the NWP models is analyzed at discrete forecast times. As a result, it is difficult to place into perspective a set of forecast characteristics at one particular time level with another. However, by observing model output in the continuous time domain, we can overcome the above drawbacks and observe features of NWP models that otherwise would not be apparent or noticed. This is the objective of my project.

Present military operations are at least as dependent upon the weather than at any time in the past. Newer operations will involve more complex and sophisticated systems that are weather dependent. Thus, the search for better methods of observing and predicting meteorological conditions may lead to models that can help the Air Force mitigate the environmental effects on their missions.

The results from this project were used to aid in the evaluation of a theater-scale NWP model's capability to make useful predictions of clouds and precipitation in the six through twelve hour range. The output from these models may eventually be useful in aiding tactical operations over areas approximately (500 x 500)Km^2.

The first step in the animation process was to run the NWP model on the CYBER computer system. Then the output wind data files (called UCOMP.DAT and VCOMP.DAT) were transferred to the AIMS VAX system to be used by the AIMSVEL.EXE NCAR graphics program. This run produced another file called FOR002.DAT which contains GKS Metacode that instructs the computer where to draw the graphics. The last step was to run the TOONS.COM program which utilizes the FOR002.DAT file and creates the frame files. It is these files, when loaded into the ADAGE image processing system, that are animated and viewed on a special CONREC video display terminal (VDT).

To load the ADAGE with the frame files, I ran a program called LOAD_ADG.COM. Then I ran CONTROL.COM and CONTROL.EXE to start the animations on the ADAGE. These animations were viewed on a CONREC VDT screen and were controlled by commands input through the keyboard. One can stop the animation, view one frame at a time backwards and forward, and even animate backwards to find out what exactly is going on inside the NWP model.

Throughout this process I used computers ranging from the Digital VAXstation 3100 and the Zenith 100 PC to the Sun Microcomputer. I also had to learn Fortran and the NCAR graphics package to run those extensive programs.

From watching the images on the CONREC screen, it is evident that the predicted winds changed more rapidly during the first third of the program than at any other time.

This is due to an adjustment process where the winds and temperatures mutually adjust to each other. And after the first third, the program creates a convergence zone down the middle of the domain. Why does the program act this way?

In Figure 1 and 5, the arrows outside the green box represent the set boundary conditions. These boundary conditions are actual wind data recorded at a site. The arrows inside the green box represent the model's calculations. These computer generated wind arrows should show some change, but they should not deviate too much from the set boundary conditions.

But what we are finding is that the program rapidly changes during the first third and then settles down with a convergence zone towards the middle. Figures 1, 3, 4 and 5 help to show why the model creates this zone. The blue arrows correspond to the strong lower level winds and the red arrows correspond to the light upper level winds. The black dashed line divides the hill in half as does the green 'slice line' of computer observation in half (example is on Figure 2).

In Figure 1, the right side of the blue line corresponds to Figure 3's right side of the black dashed line (similarly, in Figure 5, the right side of the blue line corresponds to Figure 4's right side of the black dashed line, etc.) ; only the strong lower level winds are displayed in Figure 1. And also in Figure 1, the left side of the blue line corresponds to Figure 3's left side of the black dashed line; only the light upper level winds are displayed.

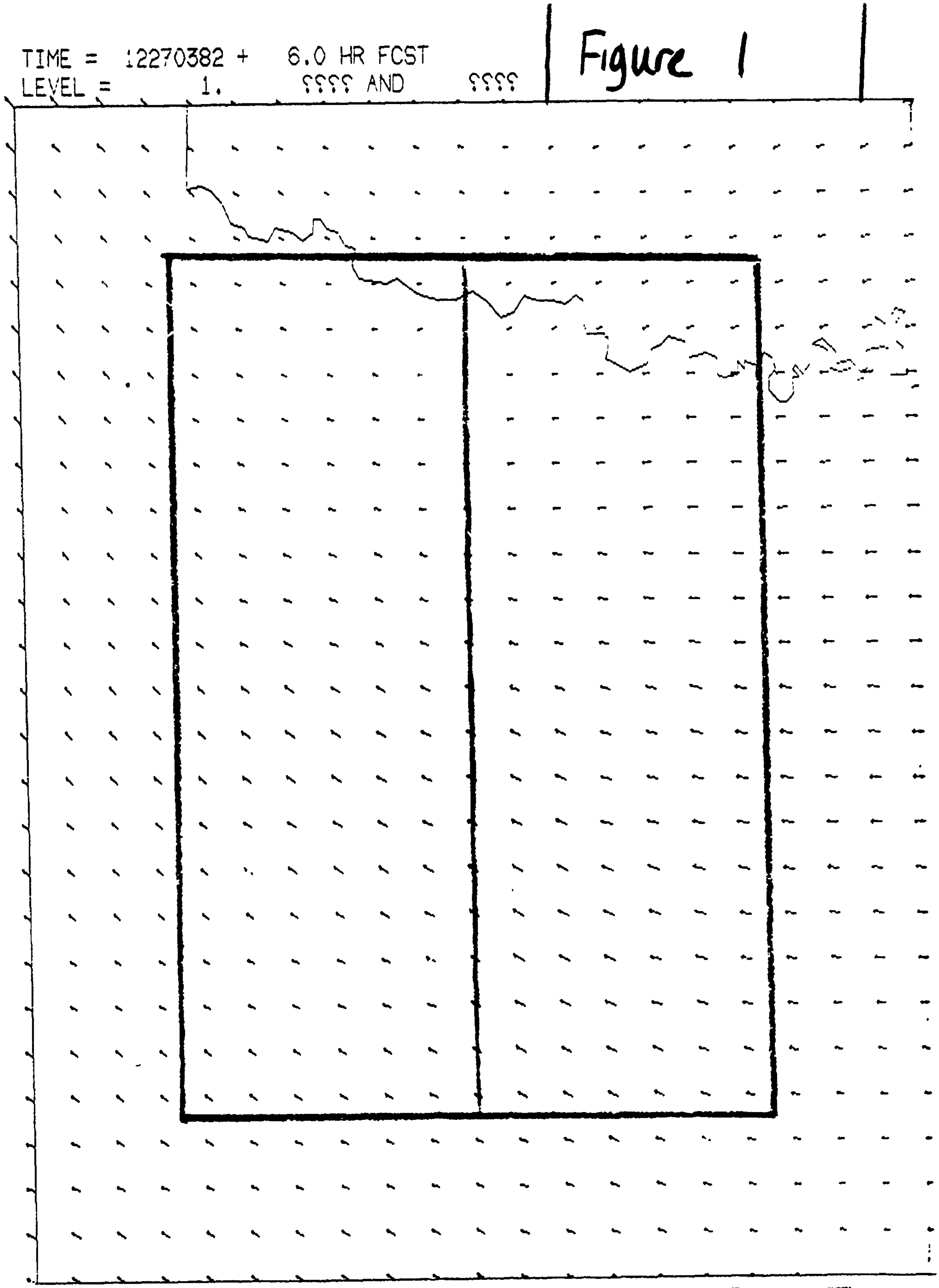
So, during the first third of the program (Figure 3), the strong lower westerly winds are blowing up the hill, which acts as a ramp, nullifying and taking over the light easterly upper level winds. As in Figure 1, the arrows are going one way. And as you can see, the arrows on the right (Figure 1) are slightly larger than the arrows on the left (the larger the arrow, the stronger the wind). This size difference can be accounted for since the left side light upper level winds in Figure 3 are being taken over by the stronger lower winds. And the resistance of the lower level winds meeting the upper level winds slows down the lower winds to a small degree (evident in Figure 1).

But, as the strong lower winds die down in the last two thirds of the program (Figure 4), the lighter upper level winds are greater than the lower level winds. And since the lower level winds do not affect the upper level winds, as in Figure 3, you see the left set of arrows in Figure 5 (easterly winds) pointing towards the blue line and consequently, the right arrows (westerly winds) pointing towards the blue line (N.B. Figure 5 was only an estimate that I produced by hand). This accounts for the appearance of a convergence point in the middle of the computer data.

It was evident, after a few revisions of the data, that the NWP model was accurately forecasting the wind. My goal for this summer project was to prove that the computer generated forecast models could accurately predict the weather. And these results were used in the evaluation of a larger theater-scale NWP model's capability of making predictions on clouds and precipitation in the six to twelve hour range. The

output form these larger theater-scale models may eventually aid the Air Force in tactical operations over areas $(500 \times 500)Km^2$.

Computer generated forecasts are growing in complexity as microcomputers become more powerful. The program above is an example of how simple a computer forecast program can be. Until we can simulate the weather through programs, we must first be able to understand how the least complex programs relate to the weather outside. And once we understand this accurately, we can expand on the simple programs.


TIME = 12270382 + 6.0 HR FCST
LEVEL = 1. ???? AND ????
Figure 1

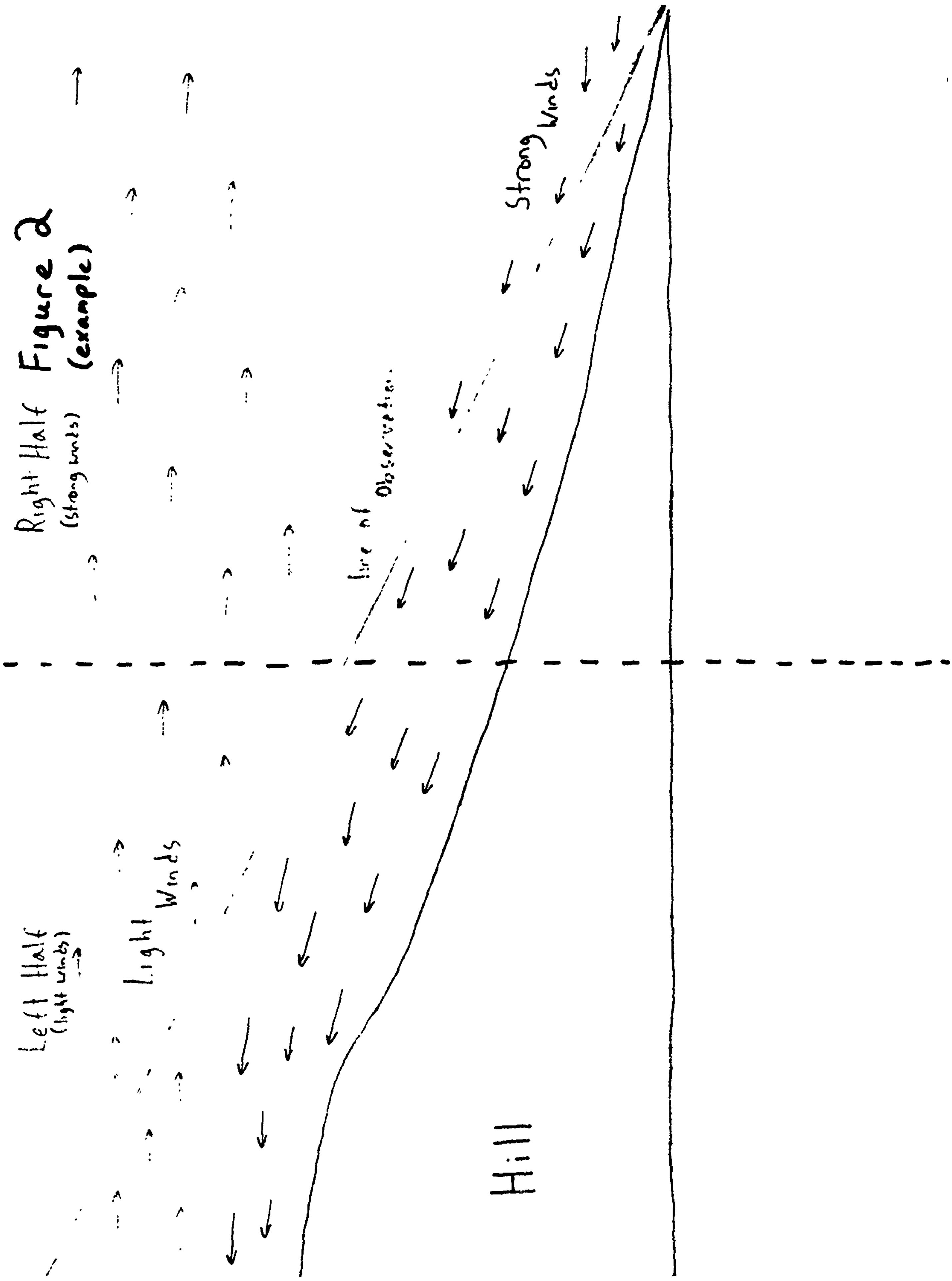


Figure 2
(example)
Right Half
(strong winds)
Left Half
(light winds)
Light Winds
Strong Winds
line of Observation
Hill

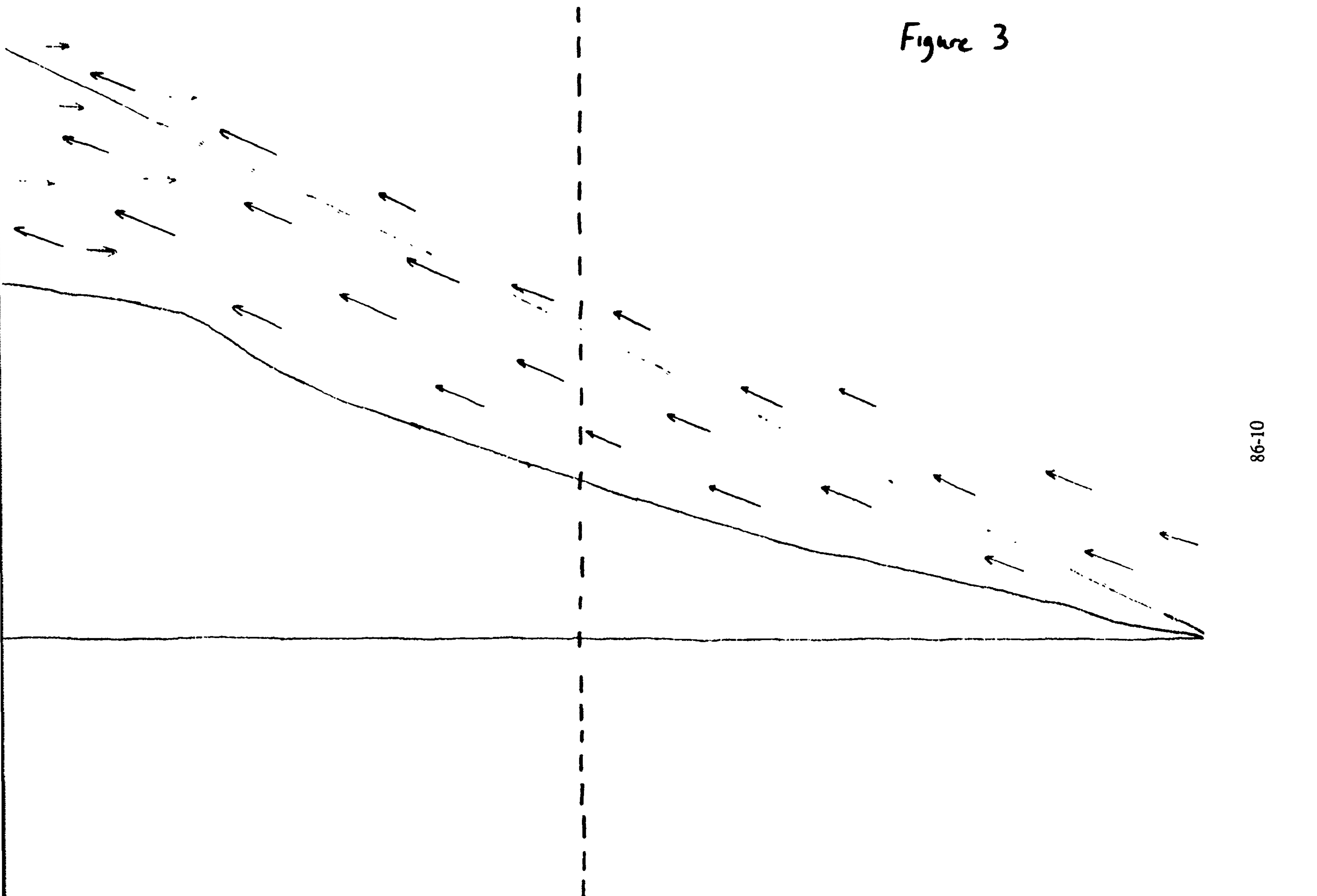


Figure 3

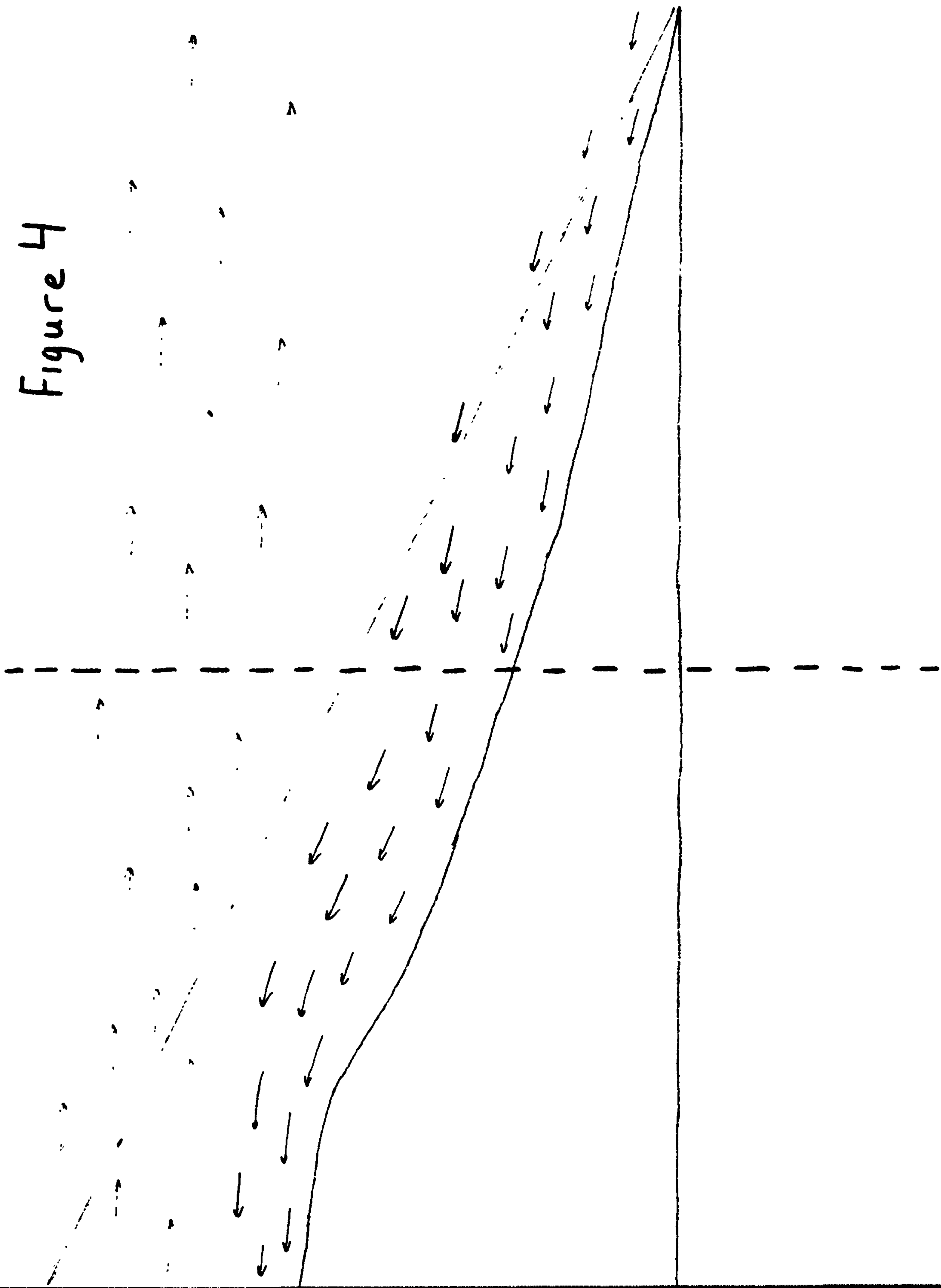
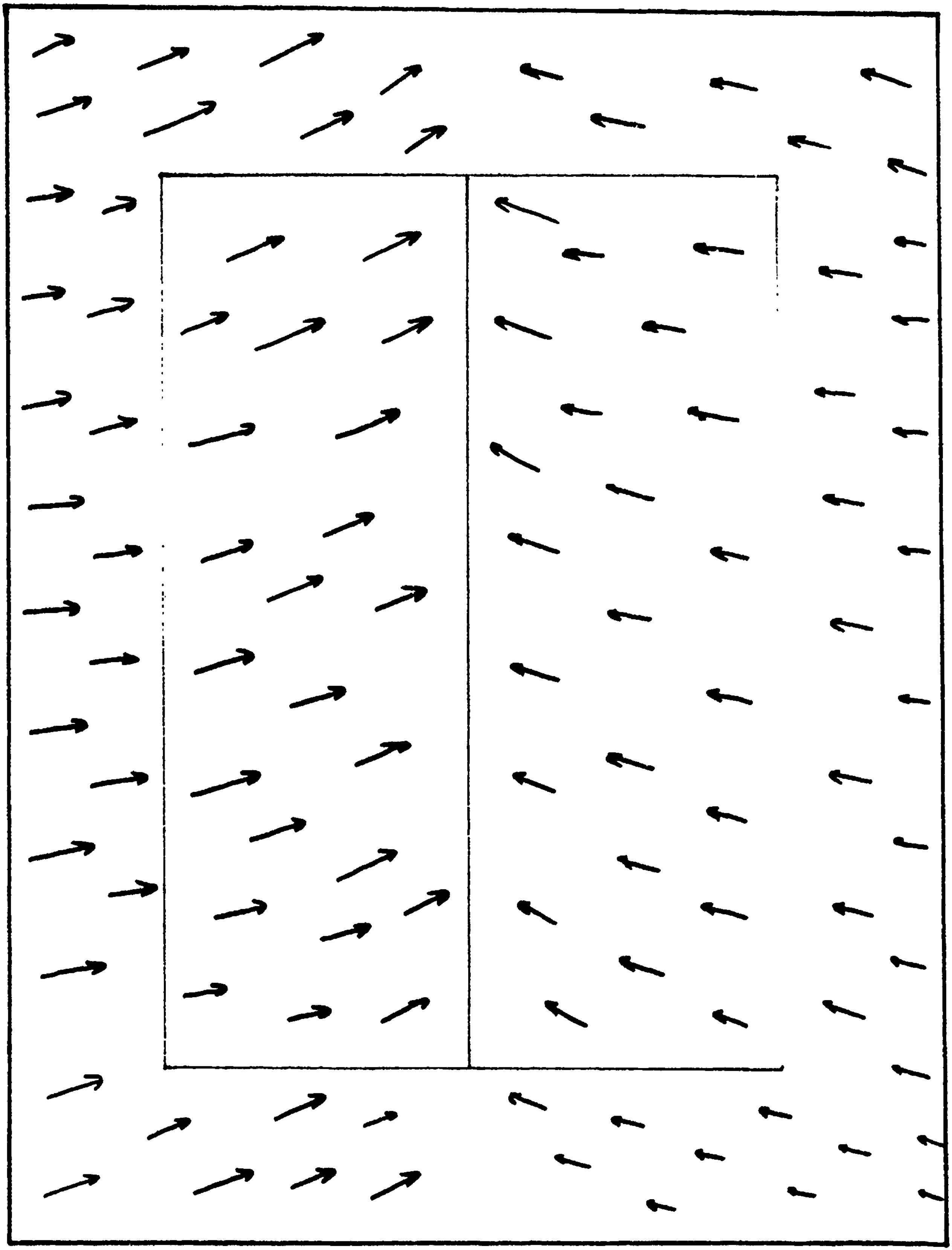


Figure 4

Figure 5



Jason Klingensmith

Final Report Number 87

No Report Submitted

GALEN MCKINLEY

AUGUST 10, 1990

SOLAR TERRESTRIAL INTERACTIONS

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ACKNOWLEDGMENTS

I would like to thank my mentor, Peggy Shea, for making my apprenticeship possible. I also thank Steve Kahler, David Webb, and Ed Cliver for their help this summer. Most importantly, I am grateful to Louise Gentile for keeping me busy and for answering my questions; to Jack Campbell for helping me out and providing comic relief; and to Sue Jacavanco for being patient with my questions and for being a friend.

GENERAL DESCRIPTION OF RESEARCH

I worked on an ongoing project to database all the data collected by neutron monitors at stations over the world concerning Ground Level Events (GLE's).

A GLE is a powerful solar flare that greatly increases the number of solar protons hitting the Earth.

There have been fifty events between February 1942 (Event #1) and May 1990(Event #50) which have been recorded by 122 various stations. Therefore, it is important to create a GLE database in which all the data will be in the same format and be on computer. The raw data that we receive is presented in many different ways and has not been processed to come up with the counts per second and percentage increase above a baseline. Standardizing and processing the data will make it accessable to scientists for study and analysis, and will help them to further their understanding of the sun.

DETAILED DESCRIPTION OF RESEARCH

This summer, I was predominantly involved with entering and processing GLE data for its inclusion in the database. I worked on a CDC CYBER 750, using a ZENITH PC as a terminal emulator.

There were several types of files I worked with on the CYBER.

An E-file contains the raw, unprocessed data that we have received from stations all over the world. In a complete file, there are uncorrected counts, pressures, and corrected counts for all the time intervals desired for the specific event. However, incomplete files are still processed and included in the database because they are still informative and useful.(See example 1)

A C-file is a processed E-file that includes counts per second and the percentage increases. The increases are what is really useful because they tell scientist how much more active the sun is during an event. The increase is also plotted to provide a visual representation of the event.(See examples 2 and 3)

A NTP file contains station information and scale factors for the raw data. These files are needed to process data because they hold information that the computer programs use to change raw data into counts per second and percentage increase. They also hold data used in the headers that top every finished E-file and C-file.(See example 4)

The catalog lists the data we have received from the stations for each event, shows which data has and has not been entered, and gives the station information used in the NTP files.

The event folders are where we store the raw data we have received from the stations. The black books are the notebooks where hard copies of the processed E-files, C-files, and plots are kept.

To process data, I would find the raw data in the event folder and enter it into an E-file designed for that event and station. I would print the file out once and check it carefully to make sure that all the numbers were entered correctly. I would then use a computer program written by Louise Gentile to process the data and generate a C-file and a plot. The E-file, C-file, and plot were then printed out, checked by Louise, corrected if necessary, and included in the black book.

I then used a hyperchannel to move the data from the CYBER to the VAX 8650. I did this because data on the VAX is more accessable than reclaim tapes used to store data from the CYBER. Eventually, the entire database will be moved to the VAX and off the CYBER reclaim tapes. Having the database on the VAX will also make it possible to send portions of the database to scientists through electronic mail.

Using this method, I processed miscellaneous data from many different events and stations to increase the database. I also updated events 35 and 37. I did this by adding any data to the existing E-files. I then reprocessed all the events and replaced the old files with the new files in the black books.

Finally, I hyperchanneled the new files to the VAX and marked them to be erased from the reclaim tapes.

I also updated the NTP files from event #8 to event #39. I checked the old NTP files against the most recent catalog. I made sure every number matched exactly, and changed any ones that didn't. It is important to keep this file updated so that the files processed with it come out error-free.

I did a short project for David Webb and Steve Kahler. They are interested in a certain type of solar event, and wanted to have a record of the cases when this type of event occured. I went through reports published by the World Data Center in Boulder, Colorado and extracted data on these type II solar radio emissions. I wrote down the station that recorded the event, the times at which they reported it, and the times of a type IV event if it occured around the time of the type II. (See examples 5 and 6)

RESULTS

The project of databasing the GLE data is not finished yet for many reasons. There is an enormous amount of data to be aquired, entered, and processed. Although much of this data has been dealt with, there is more to be done. Also, there are many problems with the data we have received. Often times we cannot interpret data, or insufficient data has been provided, or station information is incorrect. More of these problems must be resolved before it can be said that the old events are finished, and that the only thing left to do is to enter and to process the new events as they occur.

The work I was doing is useful because it provides an accessable source of information about GLE's. This will greatly help scientists studing GLE's to learn more about the sun.

OTHER INTERESTING OBSERVATIONS AND LESSONS

I am glad to have learned about working in a scientific field by experiencing and observing the working environment of a facility such as the Geophysics Lab. I realized that science is a lot of tedious work at the level of data collection and organization, but that the work at higher levels cannot be done without it.

```
                                                                        08/09/90
KUHLUNGSBO LATITUDE   54.12    LONGITUDE    11.77    ALTITUDE     70 M
KUHLUNGSBO INSTRUMENT     IGY      NEUTRON MONITOR
KUHLUNGSBO STANDARD PRESSURE       .            COEFFICIENT     .      % /
KUHLUNGSBO PRE-INCREASE BASELINE TIME INTERVAL    660706    220000-240000  UT
KUHLUNGSBO PRE-INCREASE AVERAGE COUNTING RATE               COUNTS PER SECOND
KUHLUNGSBO TIME INTERVALS    7200
KUHLUNGSBO SCALE FACTORS        5.        .        .       .       .      .
STATION    YYMMDD  SEC    TIME (UT)  CODE   UNCORR.  PRESS.      CORR.   % INC.
                           INTERVAL   TD    COUNTS   (     )    COUNTS
KUHLUNGSBO 660706 7200 000000-020000 00    25594.0    747.1        .
KUHLUNGSBO 660706 7200 020000-040000 00    25888.8    747.0        .
KUHLUNGSBO 660706 7200 040000-060000 00    25915.6    747.0        .
KUHLUNGSBO 660706 7200 060000-080000 00    26317.6    747.1        .
KUHLUNGSBO 660706 7200 080000-100000 00    26960.8    747.3        .
KUHLUNGSBO 660706 7200 100000-120000 00    26317.6    747.7        .
KUHLUNGSBO 660706 7200 120000-140000 00    26585.6    747.8        .
KUHLUNGSBO 660706 7200 140000-160000 00    26344.4    747.8        .
KUHLUNGSBO 660706 7200 160000-180000 00    26183.6    747.8        .
KUHLUNGSBO 660706 7200 180000-200000 00    25808.4    747.9        .
KUHLUNGSBO 660706 7200 200000-220000 00    26237.2    748.4        .
KUHLUNGSBO 660706 7200 220000-240000 00    25835.2    748.5        .
KUHLUNGSBO 660707 7200 000000-020000 00    26398.0    748.5        .
KUHLUNGSBO 660707 7200 020000-040000 00    25835.2    748.1        .
KUHLUNGSBO 660707 7200 040000-060000 00    25915.6    747.8        .
KUHLUNGSBO 660707 7200 060000-080000 00    26076.4    747.8        .
KUHLUNGSBO 660707 7200 080000-100000 00    26156.8    748.4        .
KUHLUNGSBO 660707 7200 100000-120000 00    26210.4    748.5        .
KUHLUNGSBO 660707 7200 120000-140000 00    26264.0    748.8        .
KUHLUNGSBO 660707 7200 140000-160000 00    26049.6    748.7        .
KUHLUNGSBO 660707 7200 160000-180000 00    26424.8    748.9        .
KUHLUNGSBO 660707 7200 180000-200000 06          .    749.2        .
KUHLUNGSBO 660707 7200 200000-220000 00    26478.4    749.3        .
KUHLUNGSBO 660707 7200 220000-240000 00    26317.6    749.9        .
*
*****************************************************************************
                                                         E15KLNG      08/09/90
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EXAMPLE #1   AN E-FILE

08/09/90

KUHLUNGSBO LATITUDE 54.12 LONGITUDE 11.77 ALTITUDE 70 M
KUHLUNGSBO INSTRUMENT IGY NEUTRON MONITOR
KUHLUNGSBO STANDARD PRESSURE . COEFFICIENT . % /
KUHLUNGSBO PRE-INCREASE BASELINE TIME INTERVAL 660706 220000-240000 UT
KUHLUNGSBO PRE-INCREASE AVERAGE COUNTING RATE 17.94 COUNTS PER SECOND
KUHLUNGSBO TIME INTERVALS 7200
KUHLUNGSBO SCALE FACTORS 5. . . . . . .

STATION	YYMMDD	SEC	TIME (UT) INTERVAL	CODE TD	UNCORR. C/S	PRESS. ( )	CORR. C/S	% INC.
KUHLUNGSBO	660706	7200	000000-020000	00	17.77	747.1	17.77	-.9
KUHLUNGSBO	660706	7200	020000-040000	00	17.98	747.0	17.98	.2
KUHLUNGSBO	660706	7200	040000-060000	00	18.00	747.0	18.00	.3
KUHLUNGSBO	660706	7200	060000-080000	00	18.28	747.1	18.28	1.9
KUHLUNGSBO	660706	7200	080000-100000	00	18.72	747.3	18.72	4.3
KUHLUNGSBO	660706	7200	100000-120000	00	18.28	747.7	18.28	1.9
KUHLUNGSBO	660706	7200	120000-140000	00	18.46	747.8	18.46	2.9
KUHLUNGSBO	660706	7200	140000-160000	00	18.29	747.8	18.29	2.0
KUHLUNGSBO	660706	7200	160000-180000	00	18.18	747.8	18.18	1.3
KUHLUNGSBO	660706	7200	180000-200000	00	17.92	747.9	17.92	-.1
KUHLUNGSBO	660706	7200	200000-220000	00	18.22	748.4	18.22	1.6
KUHLUNGSBO	660706	7200	220000-240000	00	17.94	748.5	17.94	.0
KUHLUNGSBO	660707	7200	000000-020000	00	18.33	748.5	18.33	2.2
KUHLUNGSBO	660707	7200	020000-040000	00	17.94	748.1	17.94	.0
KUHLUNGSBO	660707	7200	040000-060000	00	18.00	747.8	18.00	.3
KUHLUNGSBO	660707	7200	060000-080000	00	18.11	747.8	18.11	.9
KUHLUNGSBO	660707	7200	080000-100000	00	18.16	748.4	18.16	1.2
KUHLUNGSBO	660707	7200	100000-120000	00	18.20	748.5	18.20	1.4
KUHLUNGSBO	660707	7200	120000-140000	00	18.24	748.8	18.24	1.7
KUHLUNGSBO	660707	7200	140000-160000	00	18.09	748.7	18.09	.8
KUHLUNGSBO	660707	7200	160000-180000	00	18.35	748.9	18.35	2.3
KUHLUNGSBO	660707	7200	180000-200000	06	.	749.2	.	.
KUHLUNGSBO	660707	7200	200000-220000	00	18.39	749.3	18.39	2.5
KUHLUNGSBO	660707	7200	220000-240000	00	18.28	749.9	18.28	1.9

*
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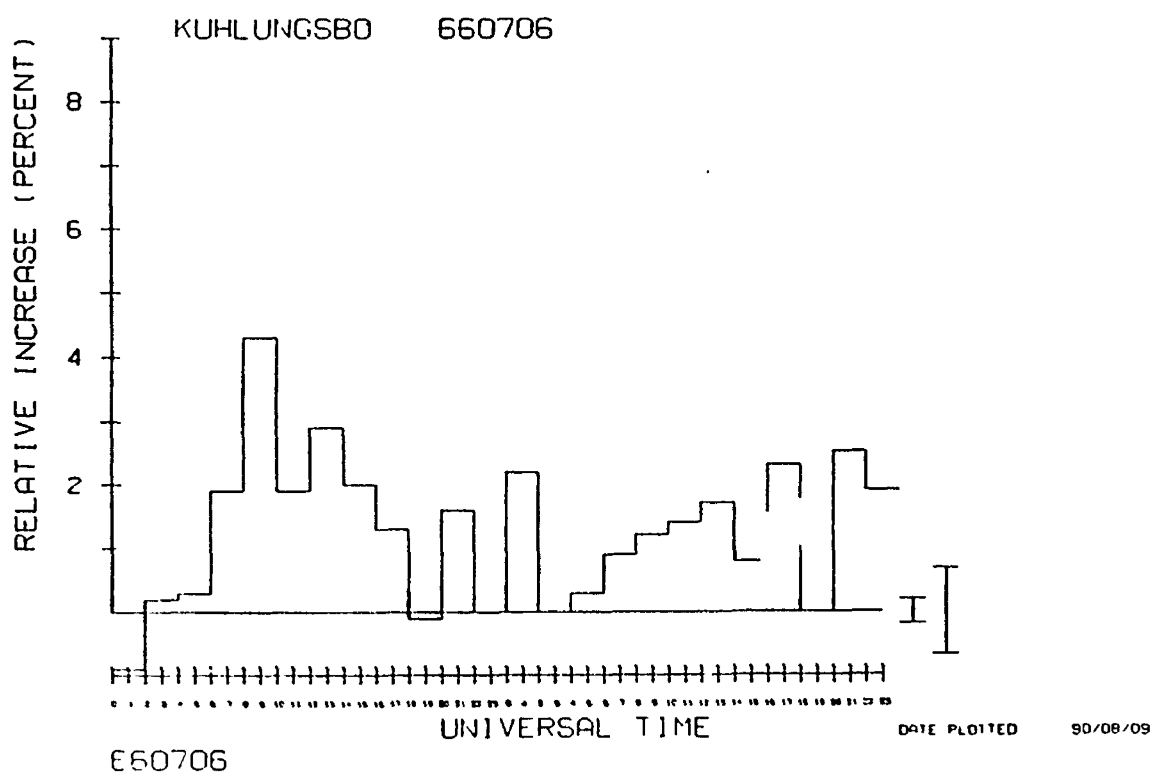
C15KLNG 08/09/90

EXAMPLE #2 A C-FILE



EXAMPLE #3 A PERCENTAGE INCREASE PLOT

07/25/90

```
EVENT # 15 660707 230000 240000
STA.NAME        LAT    LONG   ALT     INSTR STPRESS. UNIT    COEF       TIME    INTERVALS           SCALE FACTORS

12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345

ALERT         82.50  297.67    66 18-NM-64   752.00  MMHG -0.987    3600                          100.    .    .    .    .    .
ALMA-ATA-A    43.25   76 92   806    IGY       .                .   3600                           16     .    .    .    .
APATITY       67.55   33 33   177    IGY       .            -0.68   7200                           16.    .    .    .    .    .
BUENOSAIRE   -34 60  301 52     0    IGY     760 00  MMHG -0.943    3600                            8.    .    .    .    .    .
CALGARY       51 08  245 87  1128 12 NM 64   883 00   MB  -0.7718   3600                          100     .    .    .    .
CHICAGO       41.83  272.33   200    IGY     750 00  MMHG -0.96     3600                           10.    .    .    .    .    .
CHURCHILL     58.75  265.92    39 18-NM-64  1010 00   MB       .    3600                          100.    .    .    .    .    .
CLIMAX        39.37  253.82  3400    IGY     504.00  MMHG -0.96     3600                          100.    .    .    .    .    .
COLLEGE       64.08  212.17    91    IGY     745.00  MMHG -0 94     7200                           40.    .    .    .    .    .
CORDOBA      -31.42  295 80   434    IGY     722.50  MMHG -0.934    3600                          100.    .    .    .    .    .
DACCA         23.73   90.40     0    IGY    1000.00   MB  -0.73     3600                            .     .    .    .    .    .
DALLAS        32 98  263.27   208 18-NM-64   995.00   MB       .    3600                          120.    .    .    .    .    .
DEEP RIVER    46 10  282 50   145 48-NM-64   747 00  MMHG -0.987    3600                          300.    .    .    .    .    .
DENVER        39.67  255 03  1600    IGY       .                .   3600                           64.    .    .    .    .    .
DURHAM        43.10  289.17     0 18-NM-64     .                .   3600                           25.6   .    .    .    .    .
GOOSE BAY     53.27  299.60    46 18-NM-64   758.00  MMHG -0.987    3600                          100.    .    .    .    .    .
HALEAKALA     20 71  203 74  3052    IGY     709.70   MB  -0 628    7200                          128.    .    .    .    .    .
HEISS         80 62   58 05    20    IGY                        .   3600                           16     .    .    .    .    .
HERMANUS     -34.42   19 22    26  3-NM-64  1015.00   MB  -0.73     3600                          100.    .    .    .    .    .
HUANCAYO     -12.03  284.67  3400    IGY     518.00  MMHG -0.96     3600                          100.    .    .    .    .    .
INUVIK        68.35  226.28    21 18-NM-64   758.00  MMHG -0.987    3600                          100.    .    .    .    .    .
IRKUTSK       52 47  104 03   433    IGY       .            -0 69   3600                           16.    .    .    .    .    .
JUNGFRAUJ     46.55    7.98  3550    IGY     482.00  MMHG -0.96     3600                          100.    .    .    .    .    .
KERGUELEN    -49.35   70.25     0 18-NM-64   750.00  MMHG -1 01     3600                          400.    .    .    .    .    .
KIEL          54.33   10.13    54 18-NM 64   755.00  MMHG      .    3600                          100.    .    .    .    .    .
KUHLUNGSBO    54 12   11 77    70    IGY       .                .   3600                            5.    .    .    .    .    .
LEEDS         53 83  358 42   100 18 NM 64   753.00  MMHG -0.999    3600                          100     .         .         .
LINDAU A      51 60   10 10   140    IGY     740 00  MMHG -1.005    7200                           10.    .    .    .    .    .
LINDAU-B      51.60   10.10   140 18-NM-64   780.00  MMHG -0.865    3600                          100.    .    .    .    .    .
```

EXAMPLE #4   AN NTP FILE

S O L A R   R A D I O   E M I S S I O N
Spectral Observations

SEPTEMBER 1989

Observation				Decimetric Band			Metric Band			Dekametric Band			
Day	Start (UT)	End (UT)	Sta	Start (UT)	End (UT)	Int (1-3)	Start (UT)	End (UT)	Int (1-3)	Start (UT)	End (UT)	Int (1-3)	Spectral Type
09			SVTO				0909.0	0933.0	3				IV
			WEIS				0910.0	0916.6	2				IV dm
			SVTO				0911.0	0914.0	3				II
			WEIS				0911.2	0916.3	3				Spikes
			WEIS				0911.8	0938.2	3				II H,HB
			SVTO				0917.0	0929.0	3				II
			WEIS	0921.7	0925.2	3							Spikes
			WEIS				0940.7	0941.1	3				DCIM
			WEIS				0947.3	1004.9	2				IIICG
			WEIS				0949.3	0956.3	3				Spikes,DCIM
			SVTO				0950.0	0955.0	2				V
			SVTO				1039.0	1042.0	2				III
			WEIS	1052.4	1052.5	3							DCIM
			WEIS				1109.2	1111.2	2				Spikes
			SGMR				1144.0	1144.0	1				III
			SVTO				1144.0	1144.0	2				III
			WEIS				1144.3	1144.7	2				IIIG
			WEIS	1210.3	1212.5	3							IIIG
			WEIS	1241.9	1248.3	3							Spikes
			SGMR				1245.0	1248.0	2				III
			SVTO				1245.0	1249.0	2				III
			WEIS				1245.5	1248.9	3				IIIG,U
			SGMR				1248.0	0000.0	1				CONT
			WEIS				1306.7	1309.1	1				IIIG
			WEIS				1311.7	1311.8	2				IIIB
			WEIS				1404.3	1409.9	3				IIIG
			SGMR				1406.0	1410.0	2				V
			WEIS	1508.0	1509.2	3							Spikes
			SGMR				1531.0	1540.0	3				V
			SVTO				1531.0	1531.0	2				III
			WEIS				1531.6	1540.5	3				IIIGG,U
			SVTO				1533.0	1538.0	3				V
			WEIS	1533.6	1533.7	3							Spikes
			PALE				1652.0	1652.0	1				III
			WEIS				1657.8	1658.0	1				IIIB
			PALE				1851.0	1855.0	3				V
			SGMR				1851.0	1856.0	3				V
			PALE				1859.0	1901.0	1				V
			SGMR				1928.0	1932.0	3				V
			PALE				1929.0	1932.0	3				V
			PALE				1957.0	2003.0	3				V
			SGMR				2001.0	2003.0	2				V
			PALE				2200.0	2200.0	1				III
			PALE				2225.0	2226.0	1				III
			PALE				2304.0	2304.0	1				III
10			LEAR				0010.0	0011.0	1				III
			PALE				0010.0	0021.0	1				S
			LEAR				0105.0	0105.0	2				III
			PALE				0105.0	0105.0	1				III
			LEAR				0158.0	0211.0	2				S
			PALE				0159.0	0209.0	2				S
			LEAR				0219.0	0233.0	2				S
			PALE				0222.0	0226.0	2				V
			LEAR				0243.0	0247.0	2				III
			PALE				0244.0	0246.0	1				III
			LEAR				0258.0	0310.0	2				S
			PALE				0258.0	0310.0	1				S

EXAMPLE #5   A PAGE FROM THE REPORT CONTAINING TYPE II AND TYPE IV SOLAR RADIO EMISSIONS DATA

SHEET 98

89 Date	Station	dmD	Start	End		μIII	
Sept 04	LEAR	-1-	0923.0	0936.0			
	WES	-1-	0923.3	0924.8			
	WES	-1-	0963.3	0965.5			
Sept 09	CULG	-2+-	0547.	0554.			
	WES	-2-	0546.9	0550.6			
	LEAR	-2-	0547.0	0559.0			
	SUTO	-2-	0547.0	0554.0			
	SUTO	-3-	0911.0	0929.0		0909.- 0933.,3	
	WES	-3-	0911.8	0938.2		0910.- 0917.,2	
Sept 10	CULG	-1-	0232.	0233.			
	CULG	-2-	0658.	0659.			
	SGMR	-2-	1302.0	1305.0		1254.- 1316.,3	
	SUTO	-2-	1303.0	1304.0			
	WES	-2-	1303.0	1304.4			
	SUTO	-2-	1403.0	1404.0			
Sept 11	SGMR	-2-	1951.0	2003.0			

DATA PAPER (6 CC EXAMPLE #6 THE EXTRACTED TYPE II AND TYPE IV DATA

Air Force Office of Scientific Research(AFOSR)

High School Apprenticeship Program

Conducted by

Universal Energy Systems, Inc

IONOSPHERIC EFFECTS

JOHN A. KLOBUCHAR

GEOPHYSICS LABORATORY

HANSCOM AFB, MA

Jeffrey Sayasane

August 31, 1990

ACKNOWLEDGEMENT

First I would like to thank the AFOSR and Universal Energy Systems for selecting me as a participant in this program.

Many thanks to:

Pat Doherty, for finding me a place to work and letting me live after what I did to her computer.

Elizabeth Galligan, for her funny comments and remarks.

Joan Drane, it was a pleasure knowing and working with you.

Cliff Bryant, thanks for the use of your office space and desk during my first week.

Dr. Paul Fougere, for allowing me to share his office for the duration of the summer.

Gregory Bishop, for his effort in trying to find me a ride to work and for his advice.

Michael Klein, for all the talks we had, I will keep them in mind.

Charley Andreasen, for showing me how to talk to and handle a computer that beeps at you.

John A. Klobuchar, my mentor, thanks for allowing me this opportunity and experience that I will never forget.

<u>CONTENT</u>

INTRODUCTION

As an apprentice at the Geophysics Laboratory I mostly worked with my mentor's support staff and other's who required my assistance. I did jobs ranging from making copies to looking at satellite scintillation data and entering them into spreadsheets. The first couple weeks I worked with Pat Doherty doing overplots of TEC than I was started on a different project with Gregory Bishop, Michael Klein and Charley Andreasen looking at calibrations and scintillations of TEC. Although the two projects were different from another they were related in a way that they both had something or another to do with the ionosphere.

During my stay I was exposed to many things new and different to me. Before I was in the program I had only a little knowledge about computers, very little, but now after being given a chance to work side by side with computer analysts, programmers, and professionals of that field I became more knowledgeable and understanding of how computers work and how they can be applied in a myriad of different jobs. In the following pages I will be discussing my experience with computers and the research projects that I've worked on during this summer.

1.0 RESEARCH GOALS

The ionosphere is a layer made up of electrons and ions, called a plasma, extending in altitudes from 60 to 100 km above the earth's surface. One concern scientists has about the ionosphere is it's ability to disrupt and distort radio waves. The ionosphere is an important part of radiowave systems, in which to successfully operate it depends on proper ionospheric conditions. Any disturbance in the ionosphere can virtually mean the shut down of operational systems.

The Ionospheric Physics Division research to understand the influence of the ionosphere on communications and surveillance systems, to predict where and when disruptions will occur, and ultimately control the properties of the ionosphere. Researching through a broad spectrum of topics, these goals can be met.

2.0 IONOSPHERIC TOTAL ELECTRON CONTENT (TEC)

Radio waves undergo several effects when they pass through the earth's ionosphere. One of which is a retardation, or group delay, caused by its encounter with free electrons in the earth's ionosphere.

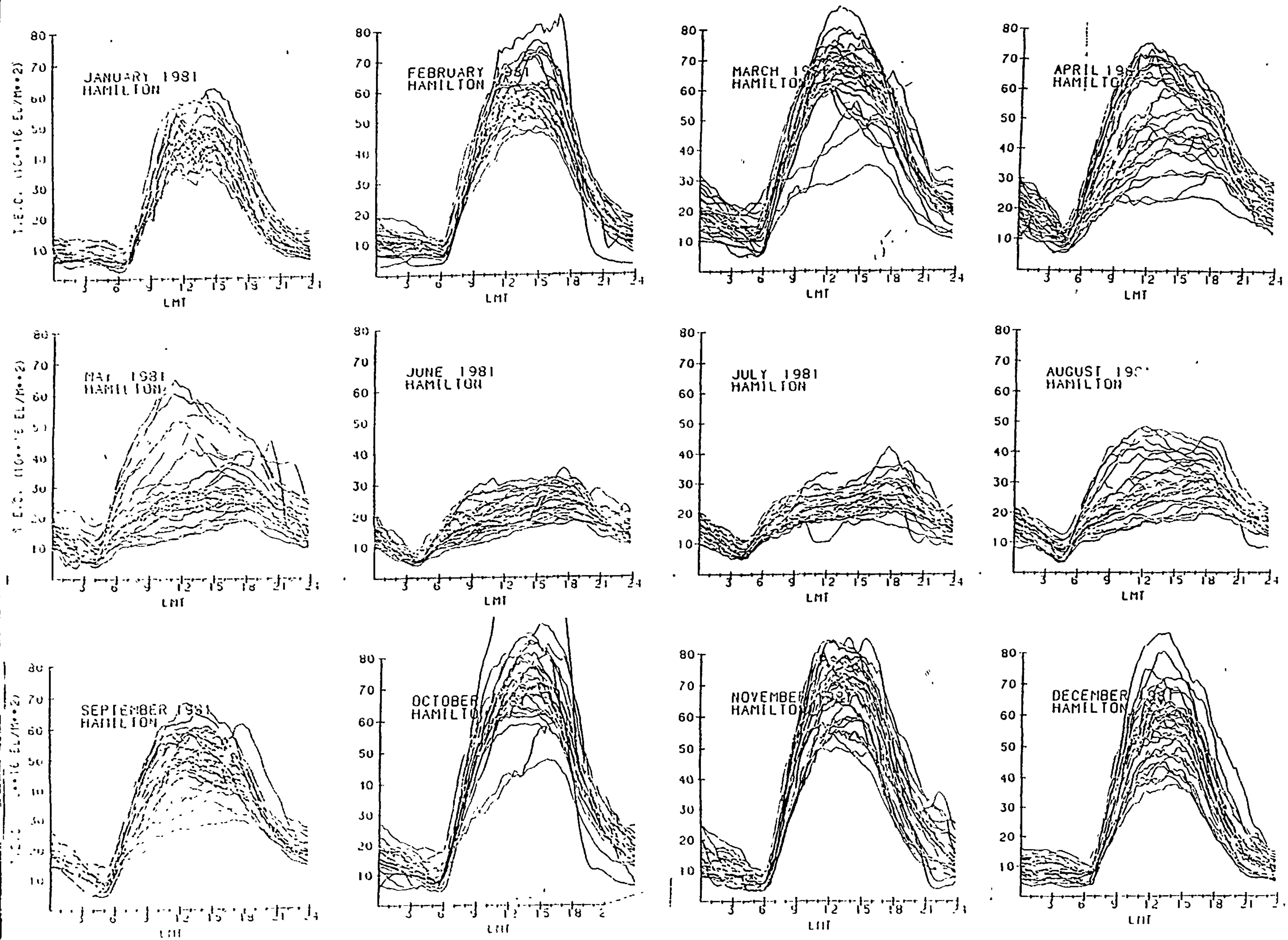
2.1 AVERAGE TEC BEHAVIOR

The cause behind the distortion in the radiowaves as they travel through the ionosphere is the total number of free electrons, TEC, or its rate of change along the path from the satellite to the ground station. It is reasoned that the F2 region of the ionosphere is the greatest contributor of TEC.

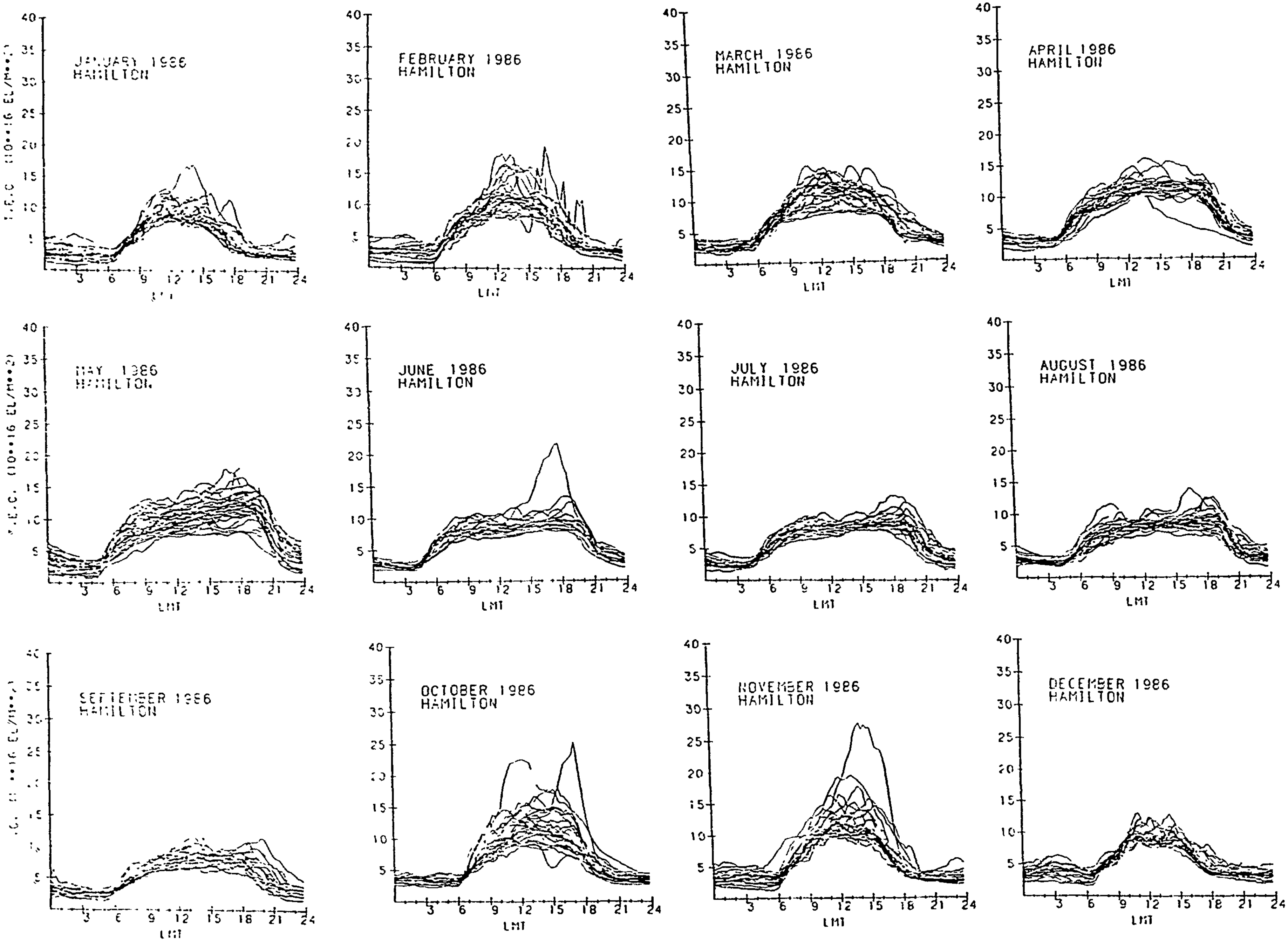
2.2 OVERPLOTS: ABSOLUTE TEC

I've been working on TEC plots with Pat Doherty, I made monthly overplots for her using different programs depending on TEC scale used for that year. Pat looks at them when they've printed out and checks to see if there are any mistake in the data. Then I take a years worth of monthly overplots and put them up on posterboards, to later be taken to the photolab. This procedure allows us to look at a year of TEC activity at once giving an overview of how TEC rise and fall in certain months or certain time of the day and year.

Figure 1 is a photocopy of monthly overplots for 1981, a solar maximum. Notice the high TEC activity and how spread out the TEC are. In October the scale was not large enough to accommodate for the relatively high activity.



JANUARY 1981
HAMILTON
FEBRUARY 1981
HAMILTON
MARCH 19
HAMILTON
APRIL 19
HAMILTON
JUNE 1981
HAMILTON
JULY 1981
HAMILTON
AUGUST 19
HAMILTON
SEPTEMBER 1981
HAMILTON
OCTOBER
HAMILTO
NOVEMBER
HAMILTON
DECEMBER 1981
HAMILTON
LMT
T.E.C. (10**16 EL/M**2)


JANUARY 1986
HAMILTON
FEBRUARY 1986
HAMILTON
MARCH 1986
HAMILTON
APRIL 1986
HAMILTON
MAY 1986
HAMILTON
JUNE 1986
HAMILTON
JULY 1986
HAMILTON
AUGUST 1986
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SEPTEMBER 1986
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OCTOBER 1986
HAMILTON
NOVEMBER 1986
HAMILTON
DECEMBER 1986
HAMILTON
T.E.C. (10**16 EL/M**2)
LMT

2.2 OVERPLOTS: ABSOLUTE TEC (cont'd)

Figure 2 is a photocopy of monthly overplots for 1986, a solar minimum, TEC activity is pretty quiet and stable throughout the entire year.

3.0 NAVSTAR

The NAVSTAR, Global Positioning System(GPS) is an advanced satellite navigation system which allow users to measure range and range rate simultaneously from four satellites to determine user position and velocity. The operating frequency of the satellite is 1.575 Ghz, which is a relatively high frequency, but eventhough, the earth's ionosphere can still disrupt radiowaves in free space. Corresponding to range errors of 100 meters the velocity could be knocked by more than 300 nanoseconds, that is 300 billionth of a second. A secondary frequency has been incorporated into the system to allow users to automatically correct both the range and range rate errors caused by the ionosphere.

3.1 GLOBAL POSITIONING SATELLITES

I've been working with Greg, Michael, and Charley on Global Positioning Satellites. The satellite receiver that is just outside their office outputs data of coherently derived, identical modulation on two carrier

3.1 GLOBAL POSITIONING SATELLITES (cont'd)

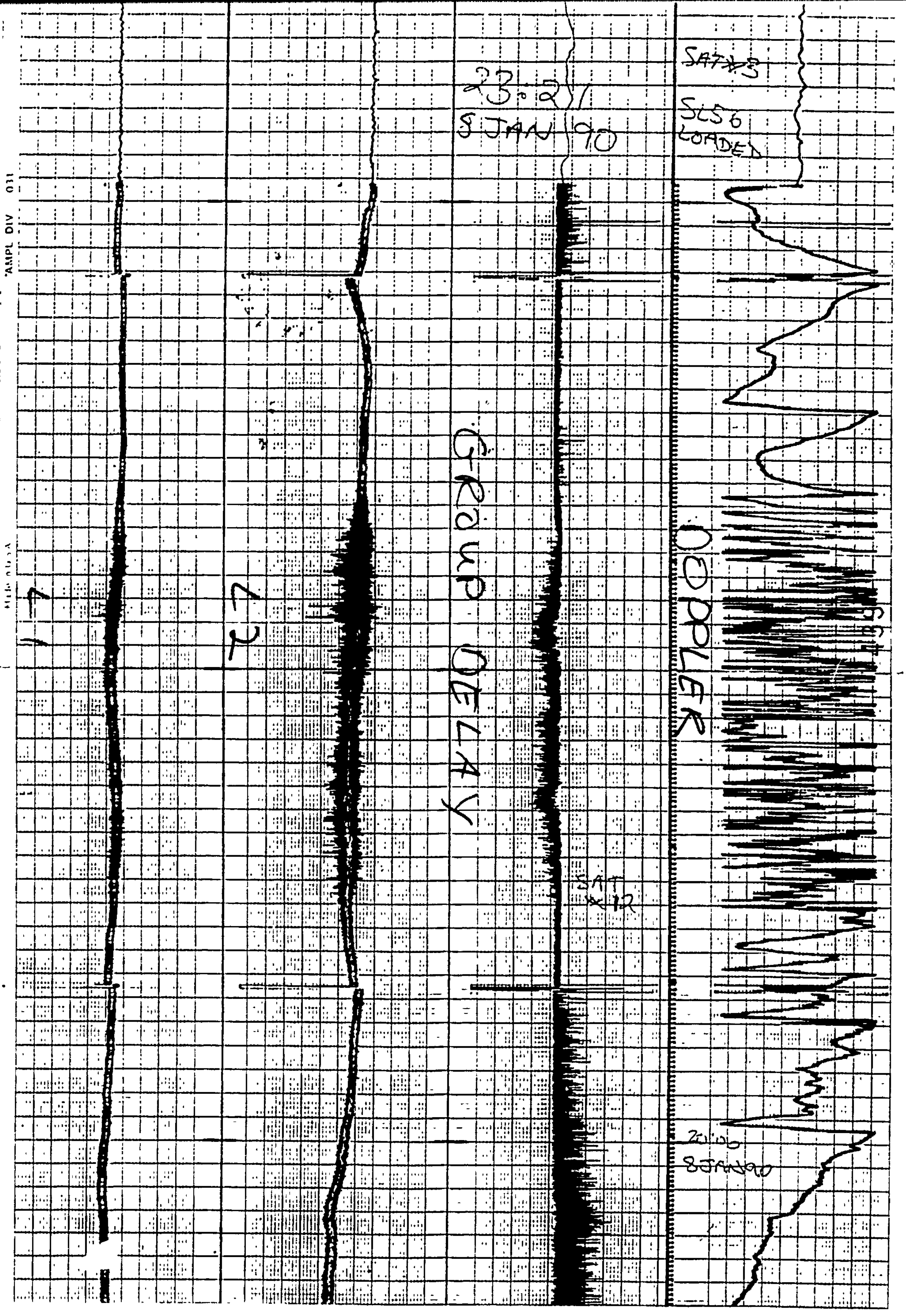
frequencies, called L1 and L2, to measure the ionospheric group path delay directly and thereby correct for ionospheric time delay.

Charley showed me how to analyze data from the receiver and enter them into spreadsheets created on ENABLE. We also tried to graph the data on SURFER, most of the time spent on SURFER was trying to develop a graph for the data that could be easily read. We never did find the right graph, but we had fun trying.

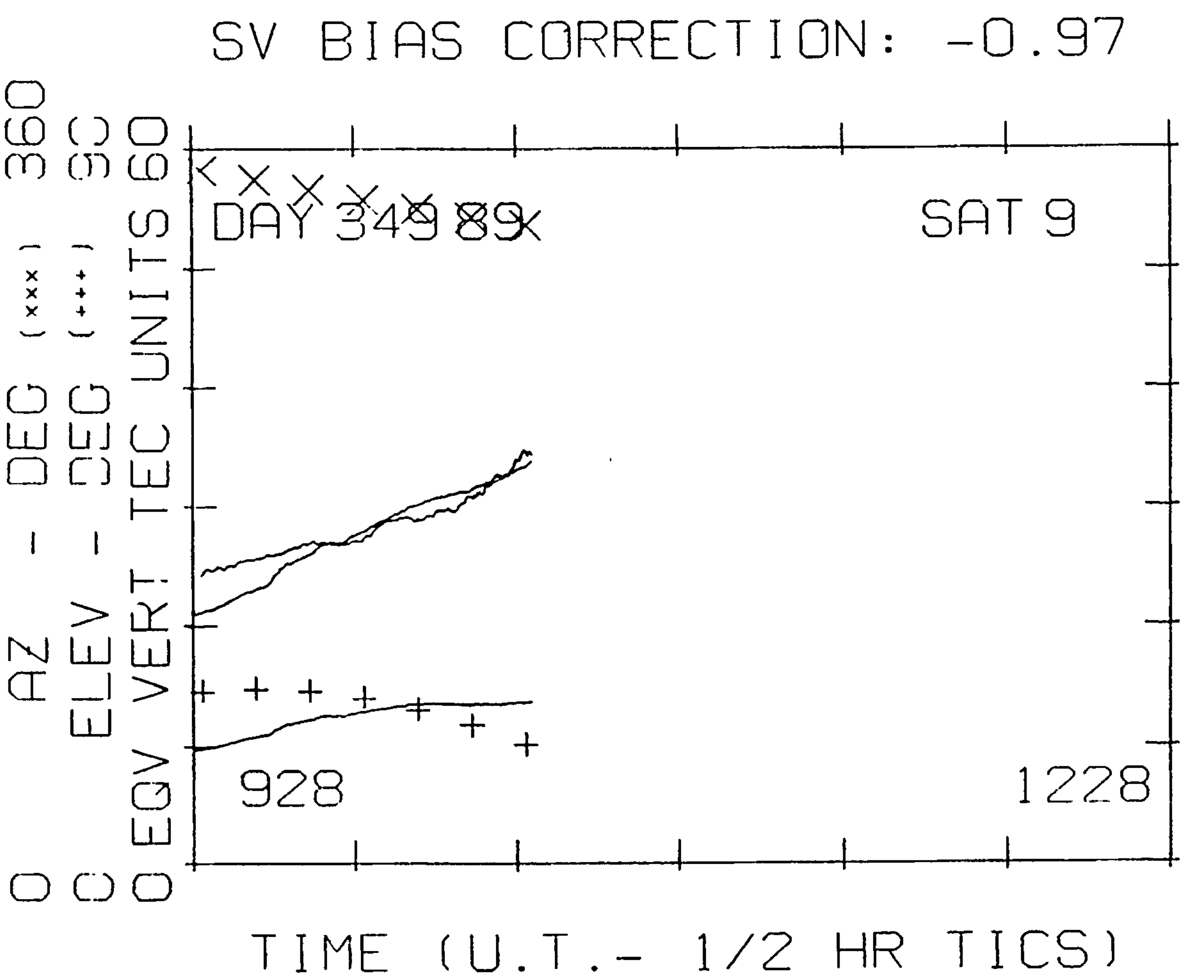
Figure 3 is a photocopy of data from a satellite receiver for 8 Jan 1990 from Shetland, between 2000 hours and 2300 hours. At this time on the data there is a doppler signature and group delay scintillation along with L1 and L2 scintillation. If so the data would be entered as 1 for each hour there is activity, in this case from 2000 hours to 2300 hours.

3.2 RUNREC PLOTS

Michael wrote a program and called it RUNREC, this program runs two types of plots, a pass file plot and a 24 hour plot. Figure 4 is a photocopy of a pass file plot of NAVSTAR satellite 13. This specific pass file is the sixth to be monitored on this tape(Tape42), the monitoring time for this pass file is from 0928 hours to 1028 hours. The


SAT#3
SCS6
LOADED
23:21
8 JAN 90
DOPPLER
GROUP DELAY
L2
L1

REF VALUE:31.99
PASS FILE:6



3.2 RUNREC PLOTS (cont'd)

receiver was turned off early because to continue with the monitoring would have been useless, the satellite was descending(+) too low for us to monitor efficiently.

A pass file plot is a plot of TEC data measured from one satellite as it passes overhead. On the plot there are 3 types of TEC data measurements shown:

- Differential Group Delay(DGD), an absolute measure of TEC.
- Referenced Differential Carrier Phase, DCP is a relative measure of TEC, ie. each measure shows the level of change from the last measure. Referenced DCP is the product of where we have correlated the DCP and the DGD.
- Equivalent Vertical TEC, a mathematically adjusted version of Referenced DCP which makes all slant measures look like they were done vertically to get an accurate. measurement of the thickness of the ionosphere•Total Electron Content.

These plots also contains information about the satellite, the •X• indicates the azimuth, and the •+• indicates the elevation. Azimuth tells what part of the sky the satellite is located in relation to the earth, and

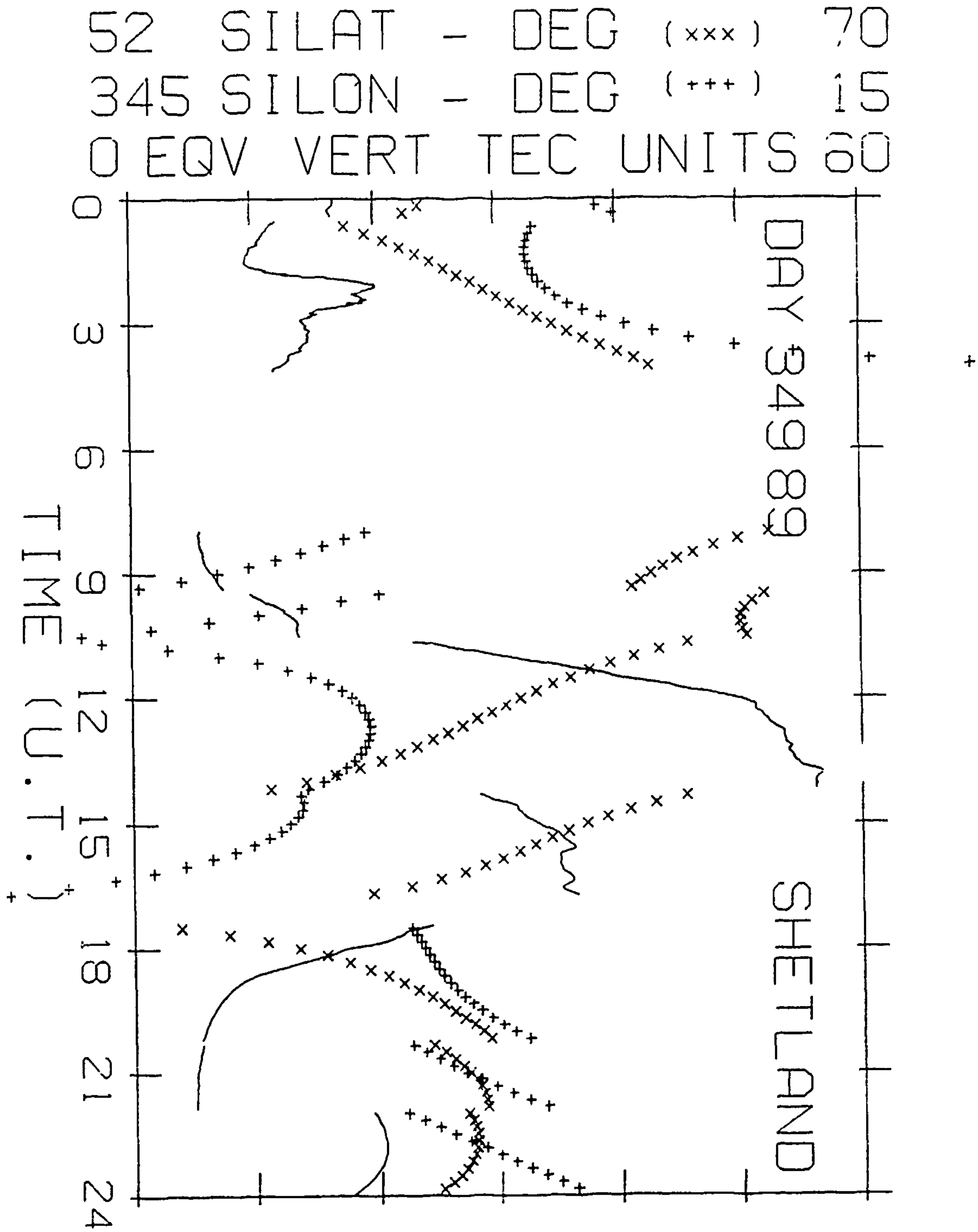
3.2 RUNREC PLOTS (cont'd)

the elevation simply says how high the satellite is above the earth's surface. Overall, RUNREC simply takes the DGD and the Referenced DCP along with the azimuth and elevation to calculate an accurate measurement of TEC.

Figure 5 is a 24 hour plot of Shetland for Day 349 89 (15 Dec 89). On this plot the •X• refers to the latitude of the satellite, and the •+• refers to the longitude of the satellite. Figure 4 equates with the third satellite monitored. Notice the almost continuous TEC curve measured. A 24 hour plot allows us to see conjunctions in TEC measures, if any, of the satellites monitored.

4.0 CONCLUSION

Working on these projects has been a fun and great experience for me. I had a most enjoyable time working and learning from the people at GL. I would just like to say to the AFOSR and Universal Energy Systems, that I think this program is really a good thing. A lot of people can benefit from it, I know I have. I know more about computers and the world of technology and science than I did before I started this program. Again I would like to acknowledge my gratitude and thanks to the AFOSR, Universal Energy Systems, and to the Air Force Geophysics Laboratory.


52 SILAT - DEG (xxx) 70
345 SILON - DEG (+++) 15
0 EQV VERT TEC UNITS 60
DAY 349 89
SHETLAND
TIME (U.T.)
0
3
6
9
12
15
18
21
24

REFERENCE

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Klobuchar, John A. Design and Characteristics of the GPS Ionospheric Time Dealy Algorithm for Single Frequency Users, AFGL/LIS Hanscom AFB.

Ionospheric Impact on Air Force Systems, AFGL Air Force Systems Command, Hanscom AFB, May 1989.

FINAL REPORT

PAUL K. SWIETEK

MENTOR DALE SINCLAIR

AIR FORCE GEOPHYSICS LABORATORY

AUGUST 26, 1990

ACKNOWLEDGMENTS

I would like to thank Universal Energy Systems for offering the summer job to me, the Air Force Geophysics Laboratory for accepting me to work at their labs and to Dale Sinclair who took time out of summer to give me a rewarding and full filling experience.

During the summer of 1990 I worked at the Air Force Geophysics Laboratory at Hanscom Air Force Base in Massachusetts. My mentor was Dale Sinclair.

The project I was to work on this summer was a solid state photomultiplier (sspm). The SSPM is a detec- -tor which is used to count single photons.

The detector was to be placed in a cylinder called a dewar. The dewar was to be pumped down to create a vacuum. Liquid nitrogen was added to begin the cooling down procedure of the dewar, then liquid helium was added to bring the dewar to a final temperature 7.0 K. Then measurements on sensitivity were to be taken.

Equipment failure prevented us from proceeding in the project. In the first stage we were to pump down the dewar but were unable because the vacuum pump broke down and had to be sent out to be fixed, which took a little over four weeks. When the pump returned the ion gauge on the pump gave us a reading of $8X10^{-6}$. For the experiment to work the pump had to be at $5X10^{-7}$. We had discovered that the copper gaskets were not sealing properly and the copper rings were to large for the opening they were to be placed in. The copper rings were ground down for a better fit and the flanges were checked for leaks. by using a helium leak detector. The copper rings showed some improvement but the two main plates also had leaks. We regreased the rubber o-rings in the plates but the ion gauge reading only came down to $3X10^{-6}$ which was still unsatisfactory. Now with the pump out of service we had to change directions.

My new project was to use a DOS operating system and the Hewlett-Packard co-processor card. In DOS I created files, formatted disks, used the command EDLIN.CON to create and edit files, copy the contents of one file to another file. I made directories by the command MKDIR and deleted some files.

Now that I had an understanding of DOS I them proceeded to make simple programs in HP-BASIC. The programs included finding factors of numbers, solving simple equations and graphics such as drawing circles. With an understanding of both BASIC and DOS my new assignment was to write a program to remotely control measurement equipment that were to be used with the SSPM. The measurement equipment included a DC power supply; digital thermometer; volt meter; pulse generator and an oscilloscope. Before writing any program, I learned the operation of each individual device. Then I began to write simple programs for each one. The first programs took readings from the instrument at pre-determined time intervals and and sent the data to either a monitor or a printer. I then took all the individual programs and combined them into two master programs, one that sent the data to a printer the other to a monitor.

My next project was to become familiar with a UNIX operating system. I used the write command to send information from my terminal to my mentor at a second terminal at the other end of the lab. With the command VI Filename I created files and directories. Also using VI I edited my files. I was even able to run a simple program in C and take the contents of two files and put them into one file.

I got to use a volt meter to to determine

where in a chart recorder a bad connection existed. The problem was found to be a broken wire that was easily replaced. I also had the opertunity to build two temperature control devices to be used in conjunction with a digital thermometer.

Probably the most important thing I learned this summer was science is not all science. A lot of time was devoted to purchasing equipment, finding funds to pay for the purchase, chasing down late shipments and having to work for the safety office that always found something wrong with what you were doing. But all in all I had a great time.

MATERIALS LABORATORY

Fatigue of Composites

By: Jennifer L. Walker
Laboratory: Materials Laboratory
Wright-Patterson AFB, OH 45433
Date: August 10, 1990

Acknowledgements:

I would like to thank Mr Jay Jira for all of his computer help, explanations, and patience; Mr Tim Johnson for his assistance on the Digital VT240; Mr Drew Blatt for his anwers to my many and various questions and the extra tour; and Dr Allen Gunderson and Dr Ted Nicholas for sharing their wisdom and encouragement. Everyone in the laboratory made me feel welcome and comfortable.

By working in the Materials Laboratory this summer, I was exposed to a science environment my previous jobs could not provide. I liked this summer job and intend to seek out other fields of engineering before deciding on a major. Thank you for three enjo/able summers in the High School Apprenticeship Program.

1. Introduction:

The Air Force has created titanium aluminide composites for application in the later stages of advanced compressor systems. The composite consists of continuous silicon fibers SCS-6 embedded within Ti-24Al-11Nb matrix material. The composite combines the strength of the fiber and the matrix material.

Fatigue crack growth tests have been run on these composites with boltholes. Tests were condusted to invesigate the effects of temperature, stress ratio, and the size of the holes. Tests were also conducted on specimens without boltholes for comparison. Knowledge of the crack initiation position is necessary for proper analysis of mechanical failure.

2. Projects:

1. Angles at which cracks initiate in previously tested titanium aluminide composites were measured.
2. The elastic compliance as measured across bolt holes during fatigue crack growth tests was analyzed by the Digital Equipment Corporation Microvax III.
3. Data was compared in subsets after creating stack histogram plots in Kaleidagraph on the Macintosh IIcx.
4. Engineering drawings were prepared for technical presentations.

3. Procedures

3.2.1. Procedure:
1. Position the straightedge (triangle) on the platform of the microscope.
2. Check alignment of the straightedge's position by running the crosshairs (on the eyepiece) all the way down its y-axis. A margin of .100 mm error was allowed since it could change the measure of an angle by only .9 degrees.
3. Remove any tabs from the specimen. (Tabs disturbed alignment.)
4. Slide a titanium aluminide composite specimen against the straightedge onto the platform.
5. Zero the bolthole of the specimen. (The eyepiece had cross-hairs to enable accurate measurement.)
   a. Center the normal to the circle on 100x to create the y-axis.
   b. Check the centering of the y-axis on 50x to double-check the original judgement.

c. Create the x-axis in the same manner. Some circles were unevenly elliptical on the sides; for these cases, the x-axis was compromised to achieve a median between the radius of the different curves. The x-axis was difficult to determine on curves less than a semi-circle, so that data was not used extensively in the study.

d. Check the centering of the x-axis on 50x to double-check the original judgement.

e. Bring the platform to the center of the bolthole.

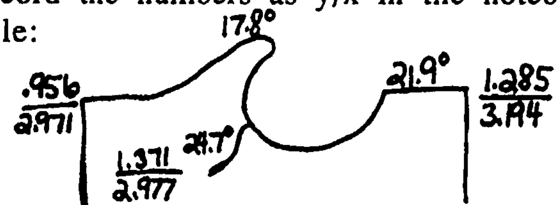
f. Check the specimen on 100x. (The specimen should not be seen.)

g. Double-check the specimen on 50x. The specimens with a diameter of approximately 3 mm should look centered. Specimens with a diameter of approximately 6 mm should not be seen; the light will shine through the bolthole and not on the specimen.

6. Move the platform in the appropriate directions needed to measure the cracks. Place the center of the cross-hairs either onto the head of a crack or a point of failure.

7. Record the numbers as y/x in the notebook as a diagram.

Example:



8. Find the angle of the begining of the crack by dividing the y-value by the x-value. Then take the arctangent to get the angle measure. Record the angle measure.

9. Enter the data into Microsoft Excel (spreadsheet) to keep files updated.

3.2.2 Procedure:

1. Reduce data file to approximately ten measurements for a temporary sample file.
2. Run the reduced file through CPCL using .99-.9 and .7-.4 as windows.
3. If the windows fit most of the data, the entire file was run through CPCL using .99-.9 and .7-.4 as windows. Otherwise, more appropriate windows had to be found.
4. The results were then plotted.
5. Steps 2-4 were repeated with .1-.01 and .7-.4 as windows.
6. Plots with data "fliers" were redone.

a. The "fliers" were deleted from the main file.
b. The file was run through CPCL again.
c. The data was replotted.

3.2.3. Procedure:

1. The data was transferred from Microsoft Excel to Text format.
2. A stack histogram plot was created from all of the data using Kaleidagraph. The summary statistics were included.
3. The data was organized into the following subsets:
    1. All diameter = 6 mm holes
    2. All diameter = 3 mm holes
    3. All 650°C diameter = 6 mm holes
    4. All 650°C diameter = 3 mm holes
    5. All 26°C diameter = 6 mm holes
    6. All 26°C diameter = 3 mm holes
    7. Same as 3, except cycle count < 10,000
    8. Same as 3, except cycle count > 10,000
    9. Same as 4, except cycle count < 10,000
    10. Same as 4, except cycle count > 10,000
    11. Same as 5, except cycle count < 10,000
    12. Same as 5, except cycle count > 10,000
    13. Same as 6, except cycle count < 10,000
    14. Same as 6, except cycle count > 10,000
4. A stack histogram plot was created for each subset. The summary statistics were included on each one for more data comparison.

3.2.4. Procedure:

1. An engineering drawing was created using the Macintosh application into MacDraft to prepare it for technical presentations.

4. Accomplishments

1. A data base for the fatigue crack growth tests has been prepared for engineers to use on Microsoft Excel.
2. Hard copies and files created of the elastic compliance on the Digital Equipment Corporation Microvax III are ready for analysis and comparison by the engineers.
3. Stack histogram plots will provide more data comparison and a data base for engineers.

4. An engineering drawing has been prepared for technical presentations in MacDraft.

References

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OCCUPATIONAL AND ENVIRONMENT HEALTH LABORATORY

AUTOMATED HEAT STRESS MEASUREMENTS

STUDENT: GARY C. NEW

MENTOR: CAPT DAVID CARPENTER

LABORATORY

AIR FORCE OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY

DATE: 14 AUGUST 1990

II. ACKNOWLEDGEMENTS

I express my grateful appreciation to the Air Force (AF) for offering me this summer apprenticeship program through the AF Office of Scientific Research. My special thanks are extended to David Carpenter who served as my mentor. His personal example, professional knowledge, and motivating influence helped me complete this effort and learn many new ideas. I also wish to thank the other EHI staff who helped me so much each day (Sgt Laporta, Capt Mader, Sgt Shillings, and Lt Herman) and the numerous staff at USAF School of Aerospace Medicine (SAM) who helped me collect data.

A U T O M A T E D   H E A T   S T R E S S

M E A S U R E M E N T S

III. GENERAL DESCRIPTION OF RESEARCH

3.1 WHAT WAS DONE

This study addressed several scenarios to try to answer some of the many questions regarding heat stress to the human body. This report documents the research, the equipment, and the other laboratories that aided in this project. We placed stress monitoring equipment on numerous people (often me) and monitored their heart rate and temperature to test our ideas about heat stress in different conditons.

3.2 WHY MEASURE HEAT STRESS?

Does it sometimes get so hot that you can barely stand it? What if you were out in the desert in the midst of a battle where chemical warfare agents were being used. ou might not think it, but many of the soldiers around you might for seemingly no reason start taking off their gas

masks and inhale contaminated air. You probably would think they must be crazy to do such a thing, but the scenario I presented to you happens. The reason for this is heat stress. What happens is inside the suit energy can not be released because there is no evaporation present. Thus the temperature gets to be ten to fifteen degrees higher than the actual temperature. It is important to know at what point we are beginning to get close to a heat stress condition and be able to predict it early. Questions that might be asked are: Do all humans have the same maximum heat stress level? Is it bad to sustain a high heat stress level for a long period of time? Questions such as these were asked in this project dealing with heat stress.

3.3 APPLICATION OF RESULTS

Heat stress as explained above has caused the loss of many valuable lives and possibly the loss of many battles. In order to prevent such further useless deaths we must first know what is heat stress and what causes it. By better understanding the characteristics of heat stress we can get greater performance out of people in hot conditions without causing problems with their health.

IV. DETAILED DESCRIPTION OF RESEARCH

4.1 DEFINITION

First we must define heat stress. Heat stress is a condition of the body where it can no longer rid itself of the heat energy which is produced or the cooling is so minute that it is ineffective. Their are many factors that must be present before heat stress can occur. Some of the major factors that result because of heat stress include: heart rate, core temperature, and workload. One other factor, time, is very important because it can either amplify or lessen the magnitude of the heat stress when the other three factors are present. Heart rate shows how well the body is dealing with the energy that was produced. The higher the temperature is the more the heart has to pump cool new oxygen in so as to cool the body down. This is one of the ways the body is cooled. Core temperature also shows how well the body is being cooled. If the body is not releasing energy through evaporation the core temperature will be very high and visa versa. Workload is an important factor, it determines how quickly the heat rate and temperature goes up. It is obvious that the harder one is working, the quicker the heat rate and temperature rise. Likewise, the less one works the slower the heart rate and temperature rise. If energy cannot be released heat stress

is the result.

4.2 LITERATURE SEARCH

Before entering this project it was obvious that I needed to learn what heat stress was and what other studies had already been done on the subject. I did so first by getting literature from the laboratory library -- mostly books pertaining to the human body. One book of particular importance was Gyton (1984). I obtained an overview about how the body systems counter one anther so each were able to cool down. After familiarizing myself with the body I then turned my research toward the topic of heat stress. I also obtained several good books on this subject from the lab library. Books written by Olishifski (1976) and the Public Health Service (1973) helped me to understand the nature of heat stress.

Though I received a lot of information from the lab books it wasn't enough. I then elected to go to a better place of reference -- the base library. There I was able to extract the remaining information by interfacing through a keyboard to the CD ROM. The CD ROM is just like an encyclopedia on a compact disk. To use the CD ROM you just entered the topic in which you were looking for and it poled

every article which had to do with it. It was very efficient and I recommend it to every apprentice if one is available. The articles which I obtained were very useful in knowing what had already had been done on this subject and what needed to be done. The rest of the information I couldn't get from books my mentor generously informed me of.

4.3 APPARATUS/EQUIPMENT USED

The equipment I used was unfamiliar to me when I began the project -- except for the microcomputer. However, it was easy to learn to use and it's operation soon became routine. Some of the equipment I used included the following:

Microcomputer (Compac Portable)

Metrosonics Heat Stress Monitors

VAX Computer (the laboratory mainframe computer -- a Digital Equipment Corporaton 8650)

Weather Station, and

BOTS Balls.

4.4 METHODOLOGY

The Metrosonics Heat Stress Monitors were the primary instrument used in this project. The monitors were about the size of a walkman radio with a belt that fitted securely around the chest. The monitor monitored the heart rate and the skin temperature. The skin temperature is a valid temperature because it is close to two degrees off from the core temperature Patty (1978). The monitors were very convenient, but not very practical for everyone's use because they cost close to two thousand dollars a piece. Although it was perfect for this project. The monitors were extremely basic in their operation. They had three buttons: the first was a 'CHECK BUTTON', the second was a 'LOG/MONITOR BUTTON', and the third was a 'RECOVERY BUTTON'. The check button was used to determine if the monitor had enough battery power for eight hours, the maximum logging time. The log/monitor button was used to start and stop the logging of heart rate and temperature. The recovery button was designed to shut the alarm off after the body cooled back to normal and would then resume logging. The monitor also had four light LEDS (Light Emitting Diodes): the first was an 'ACTION (Red LED)', the second was a 'WARNING (Yellow LED)', the third was a 'NORMAL (Green LED)', and the fourth

was a 'RECOVERY (Yellow LED)'. The action LED was to show that the person had sustained a high heat stress level for longer than a minute. The warning LED was to show that if the person didn't cool down soon they would go into the action mode. The normal LED was to represent the heart rate of the person and to show they were fine. The last LED, the recovery LED, was to show the recovery of the person. So as you can see they were very simple.

To extract the data, you then connected the data logger up to a microcomputer setting the baud rate of the modem to three hundred or twenty-four hundred and then receive the data on the screen. After receiving the data on the PC it was then saved and transferred to the VAX computer. The language was very simple -- it was almost like MS-DOS. Through the VAX computer system it was easier to move the data around and to do with as needed. The VAX computer had an unlimited amount of space which was needed for the massive amounts of data that was collected. For the most part it was outstanding in its performance.

The piece of equipment that acted as my constant variable was the portable weather station. The weather station logged very accurate temperature, humidity, pressure, wind speed, and wind direction readings. The weather station was set up on two tripods. The wind speed

and direction were on one while the two temperature, humidity, and pressure probes were on the other. The probes were all connected to the same data logger which took readings every five minutes. After collecting data for several hours the data could be down loaded onto a small computer that came with the weather station. The weather station computer prompted for the number of hours of data. When the number of hours was specified the computer went from the current time back how many hours which were specified and recalled each five minute reading. The data could then be printed out. The maximum, mean, and minimum could also be calculated by the computer. The weather was a constant variable because accurate readings could always be accurately obtained.

Another piece of equipment which was used was the bots ball. The bots ball consisted of probes that could accurately read the evaporative heat energy. The bots ball was a good environmental heat stress indicator. The bots ball was a small black ball with a long metal tube with a thermometer running along in side. The tube was also filled with water. The water kept the black ball moist so it was possible to take a wet bulb temperature reading. The performance of the equipment used in this project was generally good.

The Metrosonics fulfilled the tasks which were expected of it. Manipulating the data sets with the VAX computer was a simple task once the programs were familiarized. The weather station was already in service before the project began, as were the bots balls. It could have been more detailed if time permited more work with the data.

In the process of this project it allowed for assistance from other installations that were also working with heat stress. The laboratory in which the project was associated with was entitled SAM (the School of Aerospace Medicine). The SAM laboratory has the job of researching the causes of heat stress and how to prevent them. At the time in which this project was started the SAM laboratory was in the process of evaluating heat stress in regards to chemical warfare gear.

When going to work with the SAM laboratory they excepted us gracessly. They were as interested in the new metrosonics monitors as we were. First, we evaluated the monitors by placing them on a subject exerting himself on a stationary bicycle for fifteen to twenty minutes. This is were we found what different kind of warnings the monitor associated with, such as the warning and action alerts. After becoming familiar with the monitor, we then went to a more controlled environment. These subjects that were used

were in very good physical condition. We placed the monitors on a subject with other instruments that had been standardized for this test. The subject was then placed in a full chemical warfare suit and then asked to walk upon a tread mill. The tread mill was located in a room in which the temperature and humidity were controlled factors. The subject proceeded on the tread mill until the subjects core temperature reached thirty-nine degrees Celsius. Thirty-nine degrees Celsius was the maximum heat that could be induced on any subject. The instruments which were used by SAM consisted of a chest and thigh skin temperature probes, a heart rate belt, and a rectal temperature probe. SAM instruments helped to see how accurate the monitors really were. The heart rate of the monitor kept very close to SAM's instruments while the monitors temperature probe varied. The monitor over all was very close to the actual readings. Were the SAM equipment seemed practical it was also inefficient. Were the monitors were efficient, but very impractical because of the high cost for the job they were intended for.

While studies went on in a controlled environment studies were also being done in a field environment. The field environment was uncontrolled and not as extreme. The purpose of the monitors was supposed to be efficient and easy to use. They also were designed to regulate heat

stress so as not to be subjected to mass amounts of it. This kind of study was what the monitors were designed for. This study was done without the assistance of the SAM laboratory. The studies instruments consisted of the monitors, weather station, and bots balls. The desert region in northern New Mexico was the field study environment for the second half of the heat stress project. In this desert terrain a team of about twenty persons were subjected to activities that would be a daily routine in a war time situation. In this climate their was a good possibility of any one person being exposed to great amounts of heat stress. Things such as heat stress are always present and could affect the performance of one's duties. The objective of this second half of the project was to be able to know when heat stress is present so actions could be taken to prevent the hindering of ones performance.

In this actual field test, the first step of trying to prevent heat stress was to place a monitor on each person. Second, the portable weather station was set up and functioning. Third, two bots balls were placed out in the sun -- one dry and one moistened. The dry bots ball read the black bulb temperature; the moistened one read the wet bulb temperature. The weather station and bots ball played an important factor. The both revealed what amounts of heat were present and for how long. The monitors warned when

one's heart rate or temperature exceeded a fixed point which was thought to be unsafe.

V. RESULTS

After the experimental time was over the instruments proved to be good against detection of heat stress and heat stress conditions.

The project was primarily to see if the monitors really could detect heat stress, and they did. From the studies we were able to see that all people are not the same and must be looked at as individuals. To say certain ages of people all have the same maximum heat stress level is impractical. There are many factors that play a part in determining maximum levels of heat stress. With more research one day it may be possible to detect and minimize an individuals maximum level of heat stress. Until then all we can do is try every new idea and maybe one day it will be the solution to this complex problem.

VI. OTHER OBSERVATIONS

Many measurements were obtained. The results summarized in the Appendix show the great variation in data. The graphical results shown in the Appendix were done with SAS, a statistical package. I enjoyed working with the SAS program and plotting the results. The program was easy to use and gave a good picture of how the data looked. The large variation shows that the measurement information is very specific to individuals. Further work will be done in the coming months to try to find general relationships.

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Appendices can be obtained from
UNIVERSAL ENERGY SYSTEMS, INC.

COMPILATION OF HAZARDOUS WASTE SURVEYS

BY: ANDREA PEREZ

CAPTAIN PATRICK MCMULLEN, MENTOR

BROOKS OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY

AUGUST 10, 1990

ACKNOWLEDGMENTS

I like to thank Captain Patrick McMullen for all the information he submitted to me and for guiding in my knowledge of the environmental procedures. I like to thank Dr. Grayson for helping me understand new computer programs to help me input information for the compilation of the hazardous waste reports. I like to thank Major Cintron and Sgt. Johnson for also providing me with computer knowledge. I like to thank Lt. Hedgecock for giving me the data to input in my program.

I was assigned by Capt. McMullen to take information of all the hazardous waste surveys that have ever been created and input the information from these hazardous waste reports into a program. The purpose for this is that the Occupational and Environmental Health Laboratory sometimes gets request for this information and the OEHL does not have this information on hand. By creating this program, I am compiling all of the information needed and saving time for the officers. Also, a person requesting the information can look at the variations of different surveys, instead of looking at one survey in which the methods are out of date. This program can be use by all the bases governed by the United States of America.

I obtained all the hazardous surveys that have ever been done. These dated from 1986 to the present. I wrote down all the different products, disposal methods, shop names, product categories, and bases that were cited by the surveyors.

I then entered this data into the data base program. This information would later be inputted into a program created by a computer programmer with assistance by the apprentice. The program was then tested by the apprentice to see if all the bugs had been discovered. After the program had been tested, information was asked to the program and the program compiled and distributed the information.

The program resulted in an easier mode for people to obtain data in a hurry. The program made everything more efficient. I observed that a lot of hard work and time is needed to create a program. In conclusion, the information stored in a program is very vital. It can be compared to other information. The program lets a person see the methods used in a four-year time span. I noticed a substantial difference. The methods used now are more advanced and efficient than those used in 1986. This program is beneficial because it can be used by anyone and help him/her to make decisions on something similar to what he/she is doing. Decisions will be made more clear because of this program.

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AUTOMATION

OF

WATER ANALYSIS

AIR FORCE HIGH SCHOOL APPRENTICESHIP PROGRAM

MICHAEL S. SMID

MR DURYL BIRD, MENTOR

OCCUPATIONAL ENVIRONMENTAL AND HEALTH LABORATORY (OEHL)

BROOKS AIR FORCE BASE, TEXAS

(18 JUN - 10 AUG 90)

ACKNOWLEDGMENTS:

I would like to extend a personal thanks to the following individuals who made my first work experience in the scientific area very rewarding and memorable. Their personal interest in my well being and understanding of the projects I was exposed to gave me an insight that many other high school students should have the opportunity to experience.

Mr Duryl Bird, Mentor

Mr. T. Thomas

Mr. Ron Lovelace

Mr. Ed Hrna

Mr. Richard Mendoza

TSgt Dan Thompson

SSgt Scott O'Neil

Amn Leo Longoria

GENERAL DESCRIPTION OF RESEARCH:

Within the Occupational Evnironmental and Health Laboratory (OEHL) at Brooks Air Force Base, Texas, the experiments/research that I was involved with centered on the extraction of oils and greases from soil and water samples. These samples were from the Department of Defense and governmental installations in the United States and abroad. The research was being accomplished to insure that the water and soil were meeting federal, state, and governmental safety standards for the safety and well being of personnel assigned to these installations.

The application of results for nitrates, nitrites, chlorides, sulfates, and phosphates are continuously being monitored for each installation. Once the sample has passed through the electrode, the results are electronically graphed and data captured. The peak height is lineraly related to the concentration of the respective compound in the sample. The concentration is determined by using a set of standards to create a calibration curve, milligrams per liter versus peak height. The information is collected and forwarded back to the survey team at the respective installations and monitored at their research laboratory.

DETAILED DESCRIPTION OF RESEARCH:

While working with the soil samples, I would mix 50 grams of the sample with 50 milliliters of freon and then stir. I would then filter with a funnel to remove the freon. The freon would absorb the oils and greases from the soil. Then I would take the freon and run it through a infrared spectrometer which would detect C-H bonds in the oil and grease of the sample. As the C-H bond content of the sample increased so did the peak size from the spectrometer.

To extract oils and greases from the water samples, I mixed 500 milliliters of the sample with 20 milliliters of freon and 5 milliliters of sulfuric acid in a separatory funnel. I then shook each sample for two minutes to mix the contents, releasing pressure buildup frequently. Then, I would collect the freon by filtering it through a funnel. The sample was then ready to be tested for C-H bonding by the spectrometer.

Additionally, one of the machines for water analysis needed to have the water PH level between 5 and 9 to function properly. Since the water is preserved with acid, the PH level is way below the needed value. In order to alter the PH level I would put 15 milliliters of the sample in a container and use a magnetic stir bar to mix the sample. Then I would put the electrode in the sample. Finally, I would add 6N NaOH, 1N NaOH, or .02N NaOH to raise the PH level or 1N HCl to lower the PH level. Once the PH was within the required level, the analysis for nitrate content in the sample could be completed. To test the water sample for nitrates, as well as nitrites, cholorides, florides, sulfates, and phosphates, 2 milliliters of sample were loaded onto the tray of an

Auto Analyzer II. This machine analyzed the sample by using ion selective electrods. Each test was run on a separate machine containing its respective electrodes. The first electrode was used as a reference and the second was used to analyze the sample. The laboratory is currently trying to update its facility by using high pressure and gas chromatography. The chromotograms are hooked up to a computer which aids in analyzing the output of the chromatographs.

RESULTS:

Environmental data pertaining to the water and soil analysis are deemed critical for self preservation. Within the laboratory, I observed a group of dedicated scientists and technicians both civilian and military (Air Force) working together to ensure that their tests had accurate results. These results were sent back to the appropriate installations where corrective action can be taken.

I was impressed by the number of machines, experiements, equipment. I conclude that the results of water analysis is vital for national security and for the preservation of our society. The information will help preserve and make our environment a better place to live.

OTHER INTERESTING OBSERVATIONS AND LESSONS LEARNED FROM SUMMER EXPERIENCE:

Since "water is the major constituent of living matter" and the fact that "50 to 90% of the weight of living organisms is water," it is obvious to me that water analysis is an extremely important scientific project. I learned that water acts as a solvent, transporting, combining and chemically breaking down fats, carbohydrates, proteins and other chemicals within the protoplasm. Water "plays a key role in the metabolic breakdown of such essential molecules as proteins and carbohydrates creating the hydrolysis process."

I also was given the chance to observe an electron-scanning microscope. This microscope was being used to detect the amount of asbestos in different types of samples. This microscope had the capability of magnifying a substance 170,000 times its own size. I believe this machine will help save lives by determining places that have harmful asbestos levels.

This summer experience has opened my eyes to the world of science from a different perspective. I am more aware of our Armed Forces working toward preserving and saving life, not destroying it. It is my personal hope to one day be a part of the Air Force way of life and to contribute to my country's advancements in science.

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ROME AIR DEVELOPMENT CENTER

Pre-Commissioning and Capabilities
of the Workhorse Scatterometer:
A Final Report

By: Daniel J. Abbis

ABSTRACT

The OSEL Scatter Lab, performs research work in the field of stray light, or scatter, from optical surfaces. The scatter equipment consists of a Complete Angle Scatter Instrument (CASI).

This report describes capabilities, operation, and initial setup (precommissioning) of the CASI scatterometer. The types of samples that can be measured will be discussed along with a description and examples showing the various types of data output and the formats in which the data may be presented.

ACKNOWLEDGEMENTS

We would like to thank the following people for their help in the preparation and writing of this report:

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Dan McCurry
Lauren Coman

SUMMARY

The Scatterometer at RADC has many parts that all work together to obtain the needed data. This report concerns itself with these parts as well as how to use them. It also shows the capabilities that it has. The report also goes as far as to tell how to take a system signature. It contains many experiments that show some of the scatterometer's capabilities.

INTRODUCTION

Scatter is a result of surface microroughness and contamination of optical surfaces. The microroughness is a product of three sources: non-periodic grooves parallel to surface tool marks, periodic roughness of tool marks, and nearly isotropic roughness of random orientations. Contamination consists of particulates and/or molecular films on an optic's surface, and free-floating particulates located inside the telescope or near it's field of view.

The Complete Angle Scatter Instrument (CASI) at RADC was constructed by Toomay, Mathis & Assoc., Inc. (TMA). The instrument has the ability to measure: large angle scatter, and near specular scatter. CASI is able to measure forward and back scatter from near specular to close to 90° from normal. The instrument is controlled by software that gathers the scatter measurements, and calculates and plots (BRDF, BTDF).

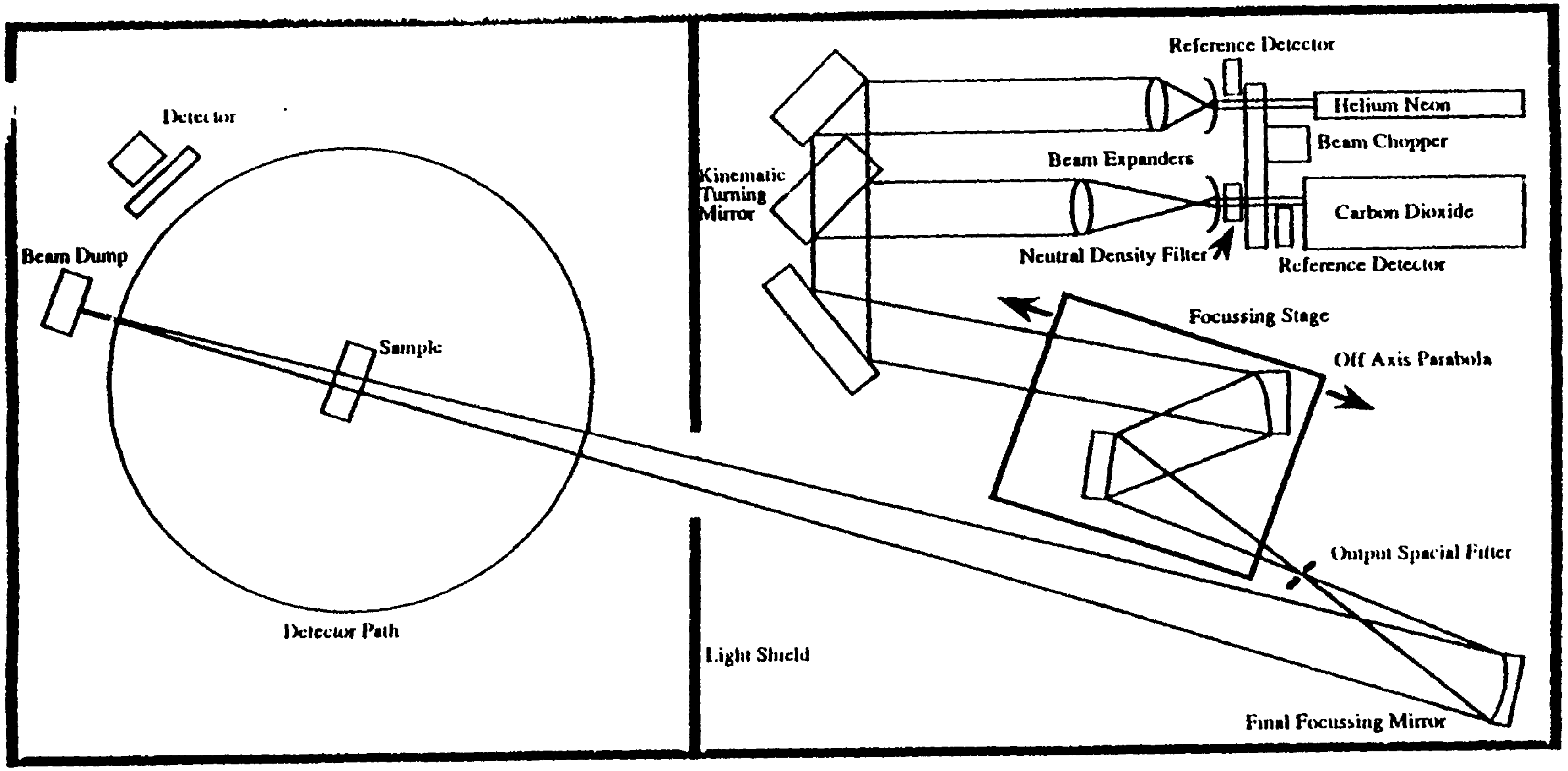


Figure 1 Scatterometer Drawing

1.0 Laser Classification

There are four main laser classification groupings. These groupings are Class I, Class II, Class III, and Class IV. The Workhorse Scatterometer at RADC uses a Class IIIB Helium Neon laser and a Class IV Carbon Dioxide laser. RADC also has a 1.09 nm NdYAG laser and a 3.39 Helium Neon gas laser. To date these two lasers have not been used with regards to the Workhorse Scatterometer.

1.1 Introduction

The Classification of a laser requires that the following be known: (a) the wavelength; (b) the classification duration; (c) average power output; (d) total energy per pulse; and (e) the laser source radiance. The lasers in use at RADC are both Continuous Wave (CW), therefore only the following parameters apply: (a) the wavelength; (b) average power output; and (c) the laser source radiance.

The Class IIIB Helium Neon laser has the following parameters:

- wavelength: 632.8 nm
- average power output: 7 milliwatts
- laser source radiance: 1.1 milliradians

The Class IV Carbon Dioxide laser has the following parameters:

- wavelength: 10600 nm
- average power output: 4 watts
- laser source radiance: 8-10 milliradians

1.2 Class III Laser Classification

A Class III laser has the capacity to cause injury within the natural aversion response time. They can not cause serious skin damage or dangerous diffuse reflections under normal use. They must have danger labels. They are also known as "Moderate Risk" or "Medium-Power" lasers. (Sliney, David and Wolbarsht, Myron: 1980. P. 7)

1.2.1 Class IIIA Laser Classification

The Class III laser grouping is subdivided into IIIA and IIIB. Each subdivision has separate characteristics. A Class IIIA laser has an output irradiance below 2.5 nW/cm^2, and the power is below 5mW. (Sliney, David and Wolbarsht, Myron: 1980. P.596)

1.3 Class IV Laser Classification

A Class IV laser may cause diffuse reflections that are dangerous to the eye and may also cause serious skin injury from direct exposure. They may cause combustion of

flammable materials. They are also known as "High Power" or "High Risk" lasers. (Sliney, David and Wolbarsht, Myron: 1980. P. 7)

2.0 Laser Controls

The safety rules for the above classifications may be summarized as follows:

2.1 Class III Controls:

Class III laser controls are as follows:

a. avoid direct exposure to eye;
b. allow only experienced personnel to operate:
c. make an attempt at enclosing as much of the beam path as possible:
d. place filters, shutters, and polarizers at the laser exit port to reduce the beam's power to the minimal useful level;
e. a warning light or buzzer should indicate laser operation:
f. operate laser in a restricted area;
g. place the laser beam path well above or well below eye level of all present;
h. use eye protection, and
i. use a key switch.

2.2 Class IV Laser Controls

Class IV Controls are as follows: (In addition to the Class III controls)

a. operate within a localized enclosure;
b. eye protection is needed for all individuals in the area, and
c. always use beam shutters, beam polarizers, and beam filters

3.0 System Safety

It is important to take a detailed look at hazard analysis and general safety procedures when planning system safety.

3.1 The Laser's Hazards Potentials -- System Safety

It is possible to develop a classification system to show the need for improvement of the safety aspects in evaluating the risks that a laser and other general hazards can present. Figure 2.

3.1.1 Laser Hazard Analysis

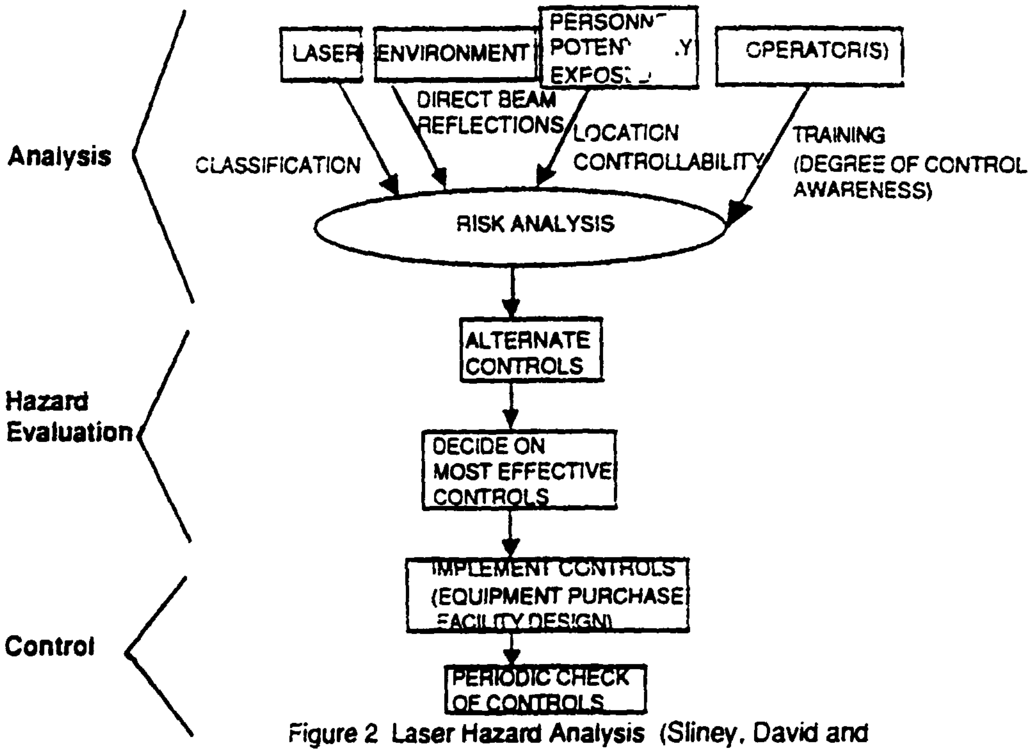


Figure 2 Laser Hazard Analysis (Sliney, David and Wolbarsht, Myron; 1980. P. 472)

3.1.2 General Concepts of System Safety

Regardless of the fact that the Bureau of Radiological Health Regulations assures that there must be certain safety features put into manufactured laser products, it should be recognized that these features are not in and of themselves the only means of reducing risks. The possibility of applying a greater amount of system safety controls in addition to the already existing features should be taken into consideration. Figure 3 shows a basic method used by system designers for finding possible malfunctions and safety hazards in a piece of equipment. (Sliney, David and Wolbarsht, Myron; 1980. P. 473)

4.0 Laser Set-Up Safety

When speaking of laser set-up safety, it is important to consider not only the laser, but also the entire laser set-up (i.e. beam paths, beam enclosures, controlled entry, etc.)

4.1 Laser Eye Protection

Safety goggles or spectacles are extremely effective when other engineering controls are not possible. It should be noted that the filter material and side shields should

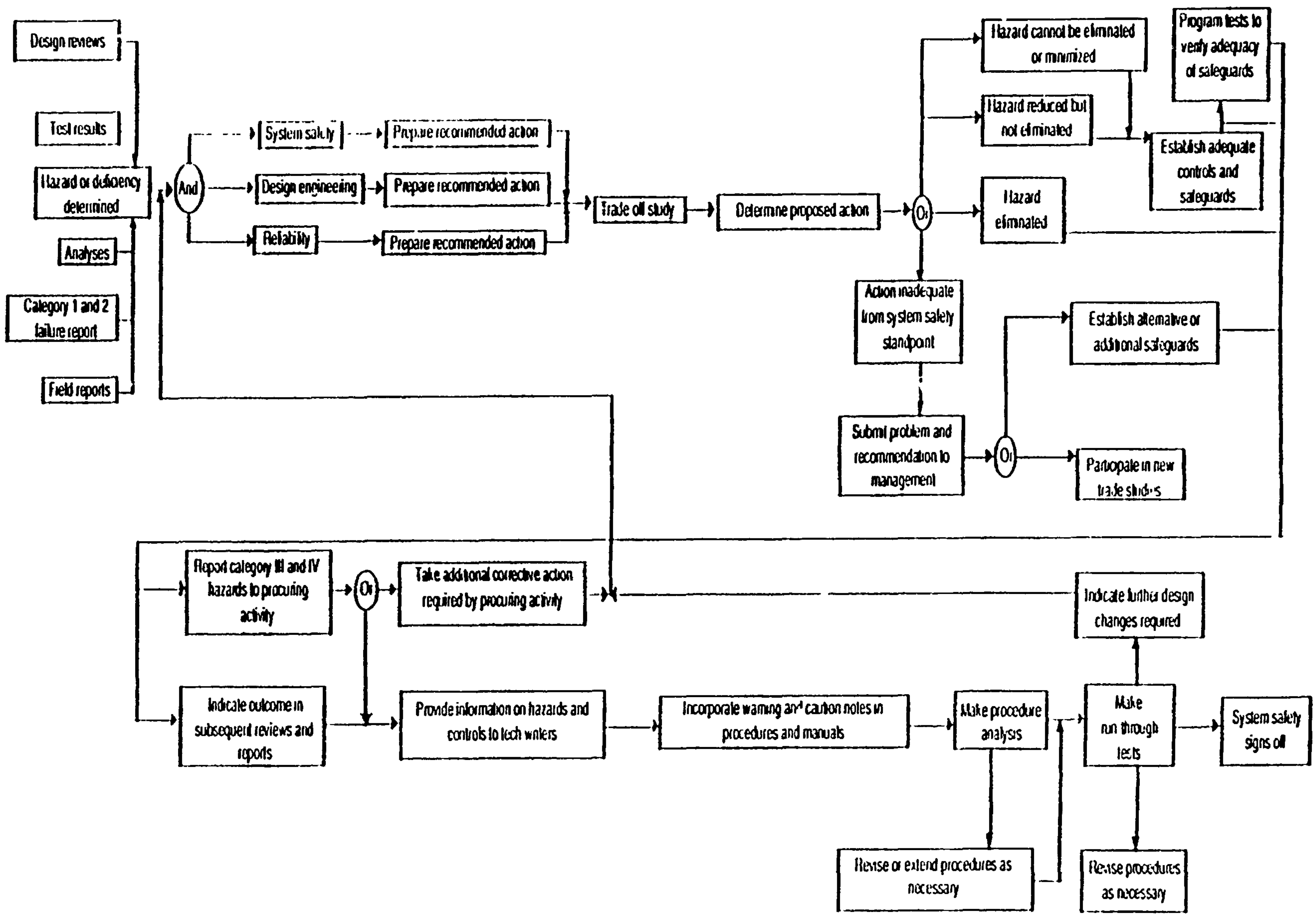


Figure 3 System Safety Flow Chart

be able to withstand the maximum irradiance encountered in the environment for at least three seconds. There are therefore many physical parameters that the goggles/spectacles must meet. Some of these parameters that must be met are: the correct protective wavelength; the correct optical density of the filter; the proper amount of visual transmittance; a high damage threshold; and the proper filter curvature. (Sliney, David and Wolbarsht, Myron: 1980. P. 10)

4.2 Diffuse Reflections

Looking directly at the beam is not the only manner in which damage to the eye can be done. Hazardous reflections are potentially dangerous to the human eye. The shaded area in Figure 4a shows the dangerous zones for intrabeam viewing of a Class 3 laser. If the output radiant exposure of a pulsed laser is increased so that the laser in considered Class 4 then the probability of eye damage is shown by the shaded area in Figure 4b.

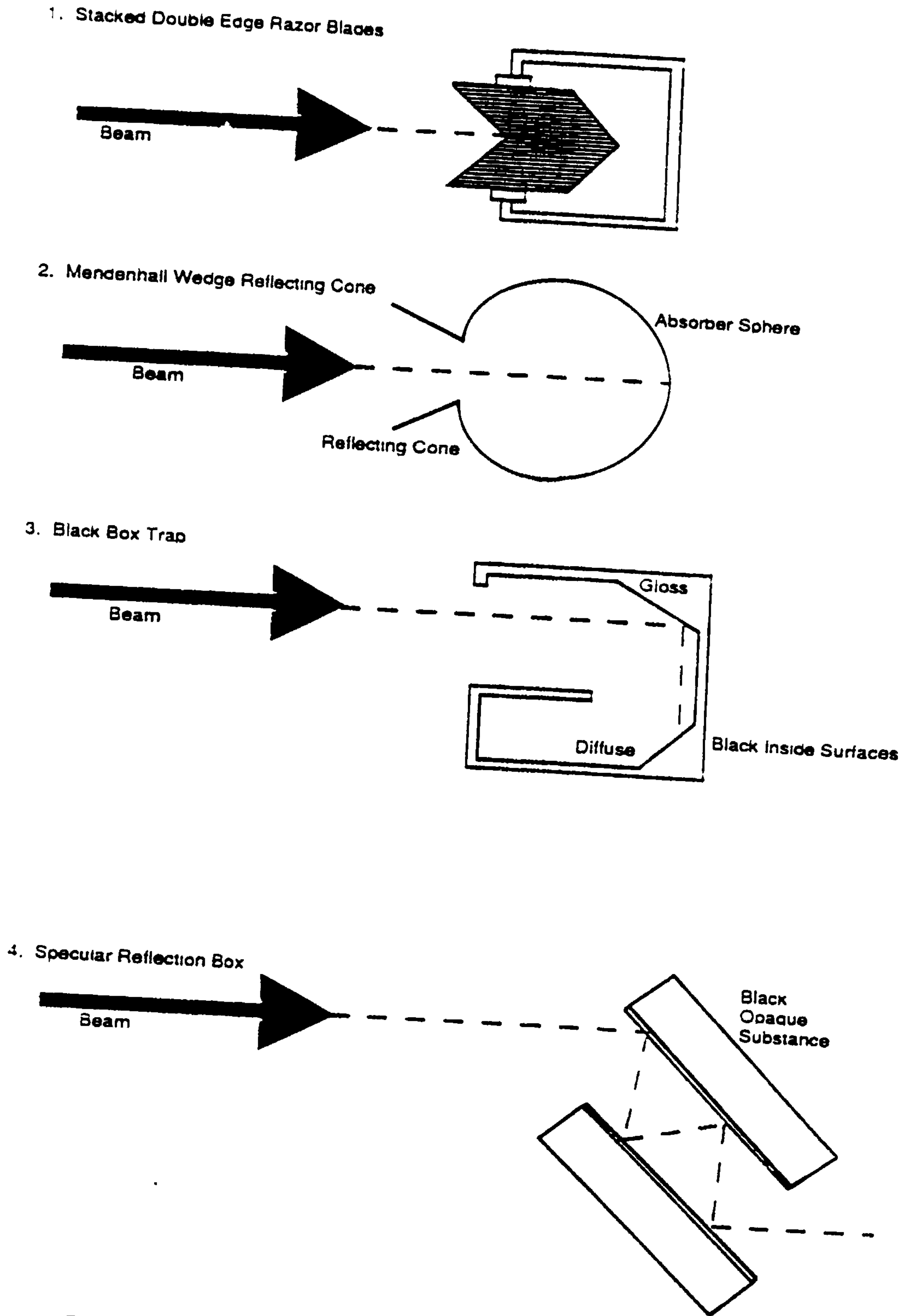


Figure 5 Beam Traps. In each of the four cases the concept is to minimize the reflected energy leaving the trap without placing too great a heat burden on the absorbing surfaces. (Sliney, David and Worbasnt, Myron; 1980. P. 570.)

4.6 Controlled Entry

For Class IV lasers and certain class III it is generally advisable to limit entry. Restrictions on entry are generally done through the use of signs, special door latches, and interlocks. Class IV lasers sometimes provide a power supply relay connector to connect with a door switch to stop power to the laser when the door is opened.

4.7 Beam Path

The main hazard that a laser beam poses, besides the primary beam itself, are any secondary beams. It is extremely important that the laser beam, both primary and secondary be located above or below eye level to reduce the risk of eye damage.

4.8 Temporary Beam Enclosures

Temporary beam enclosures are extremely helpful because they allow for viewing of the beam without posing a danger by permitting body exposure to the beam. Small portable shields of glass or transparent plastic are frequently used. Such enclosures may also reduce the problem of dust collection upon optical surfaces.

4.9 Standard Operating Procedure

It is suggested that a standard operating procedure (SOP) be written. This serves many purposes. The lab personnel are forced to consider safety and generally will follow their own rules more readily than those made by a central safety officer. (Sliney, David and Wolbarsht, Myron: 1980. P. 573)

5.0 RADC Scatter Laboratory Safety Checklist

Now that the manner in which the ideal safety cautious laser laboratory should be set up has been presented, it is necessary to take a closer look at exactly what safety devices/procedures RADC has implemented in the course of the use with the Workhorse Scatterometer:

•Operating personnel: All of the Workhorse Scatterometer personnel are completely experienced in the set-up, operation, and safety of the entire system.

•Beam enclosures: RADC does not have beam enclosures to date. A major reason for this is that enclosures would only hamper the operators from being able to change such things as the detector head's apertures, tip, and tilt.

•Filters, shutters, and polarizers: RADC has all the proper and necessary laser beam filters, shutters, and polarizers to assure a safe operating environment and testing atmosphere.

•Warning lights, buzzers, and signs: RADC has all the needed safety signs and warnings.

•Restricted area: The Workhorse Scatterometer is operated in a key locked room which is located inside a combination locked area.

•Laser beam level: The laser beam is situated so that it is above the eye level of someone sitting and below the eye level of someone standing.

•Eye protection: RADC has many different types of eye protection. RADC's collection of safety glasses/goggles has a wide variety of optical density's to assure an extremely safe operating environment.

•Key switch: All the lasers used in the Workhorse Scatterometer contain a key switch.

•Beam traps: RADC uses a stacked double edge razor blade style of beam trap.

6.0 Signal Detector Alignment

Now that the safety aspects have been covered, it is necessary to go through the needed pre-commissioning. Below is a step by step manner in which to get the Scatterometer ready to take a system signature.

Manually center the aperture Y axis stage. Install the 340 nm aperture plate. Adjust the detector post to center the aperture on the beam in Y. Choose the manual mode in the CASI software. Move the scan rotary axis in order to center the beam on the aperture horizontally by peaking the detector power reading. In order to fine tune the detector output it is necessary to adjust the pitch and yaw micrometers while watching the detected power displayed on the computer screen.

Open the alignment iris on the X stage assembly all the way. Use scotch tape to fix a piece of white paper to the front of the iris to make a diffuse spot. Remove the aperture plate and move the Sample θstage to +5 degrees from beam center. A small signal should be seen from the signal detector. Adjust the detector mount pitch and yaw micrometers to peak the signal while viewing the detector watts on the screen. Put the detector back to beam center. The detector reading on the screen should show about 2-5 mW of power and the output meter should have a positive reading. Replace the aperture and remove the paper from the iris. A signature center can now be run. (TMA (Hardware Reference Manual), April 20. 1988; pgs. 24-25)

7.0 System Initialization

This section will cover the needed system alignment/initialization procedures required immediately prior to taking data

7.1 Prerequisites to System Initialization

Once the system is set up and aligned the system initialization can be carried out. System initialization depends upon the optical train of the scatterometer being aligned well enough so that movement of the focusing stage does not require large adjustments to the output pinhole position.

7.2 Focussing the Beam

The last adjustment after the system is aligned is focussing the specular beam at the detector plane. Using the focusing stage the output pinhole and output optics are moved with respect to the focussing mirror until a tight focused spot is obtained at the detector. Moving the output pinhole towards the focussing mirror will move the focused spot away from the mirror, while moving the output pinhole away from the focusing mirror has the opposite effect and draws the focused spot in towards the focusing mirror. The goal of this step is to position the focused spot at the front face of the detector aperture. Focus is best assessed by using a piece of film at the detector and visually inspecting the spot size and shape.

The beam is considered focused at the detector when the spot appears slightly elongated in the vertical.(TMA (Hardware Reference Manual), April 20, 1988: pgs. 26-27)

7.3 Rough Centering of the Detector in Y

After the focused spot is positioned at the front plane of the detector, the detector must be moved in θ and Y so that the focused spot is centered on the face of the detector aperture. The smallest detector aperture should be in place on the detector during centering.

The initial centering is begun by making sure that the detector aperture y stage is at its center of travel. The detector pitch and yaw stages must also be near their center of travel. The detector should be roughly aimed at the sample if this is true. Rough centering of the detector will be accomplished by adjustment the height of the detector post mount. Using the y travel adjustment on the detector post mount the height of the detector is adjusted so that the focused spot of the specular beam is at the same height as the detector aperture.

Once this is completed, the detector post mount is tightened and secured in this position.(TMA (Hardware Reference Manual), April 20, 1988; pgs. 27)

7.4 Centering the Detector's Field of View

The detector's field of view is limited to an area slightly larger than the illuminated spot on the sample. Therefore, it is necessary that the detector is aimed well at the sample.

There are two degrees af freedom of detector motion that are used to aim the detector. These motions are detector pitch (up and down) and detector yaw (side to side) motion. To adjust the pitch and yaw of the detector a dummy sample must be mounted to give the detector a bright spot at the sample location to center on. A diffuse transmissive sample is needed for the dummy sample. A piece of scotch tape stretched across an iris works well. This dummy sample must be positioned in z so that it is in the center of rotation of θ_s.

Once the sample is in place, the detector is rotated about five degrees off the specular. Movement of the detector requires that the CASI software is running and that the operator has executed the manual mode that allows manual control of the instrument. Then remove the aperture. Now the detector's pitch and yaw is adjusted to maximize the signal the detector sees. After this, the smallest aperture, is replaced onto the detector, the detector is moved back to specular, and the diffuse transmissive sample is removed.

This procedure must be done at system installation and also each time the detector position on the sweep arm is changed or each time the height of the detector is changed by adjusting the detector post mount. It is also a good idea to periodically adjust this to insure the system is aligned.

7.5 Final Centering of Detector in Sample θ and Y

After the proceeding steps, the focused specular beam should be near the center of the detector aperture, the instrument should be still under manual control through the CASI software and the detector should still be in the hardware home position.

The detector is now moved by selecting the Detector Theta Axis for movement in the CASI software and stepped in θ until the focused spot is visually centered in the detector aperture.

The scan setup in the CASI Angle Scan module should be defined with the appropriate sized aperture. The y stage on the detector aperture must also be adjusted to visually center the aperture on the focused spot. The signal measured by the detector should now approach the level of the total signal.

After this procedure is done the automatic centering routine in the Angle Scan software should be run. Once this is complete the aperture Y stage should be carefully adjusted again to maximize the detected signal. The automatic routine should be run one more time if the detector aperture was moved in y.

The only reason that the entire process needs to be done again is if the system is changed. This would include changing the detector arm length or any other system alignment positions. (TMA (Hardware Reference Manual), April 20, 1988; pgs. 28)

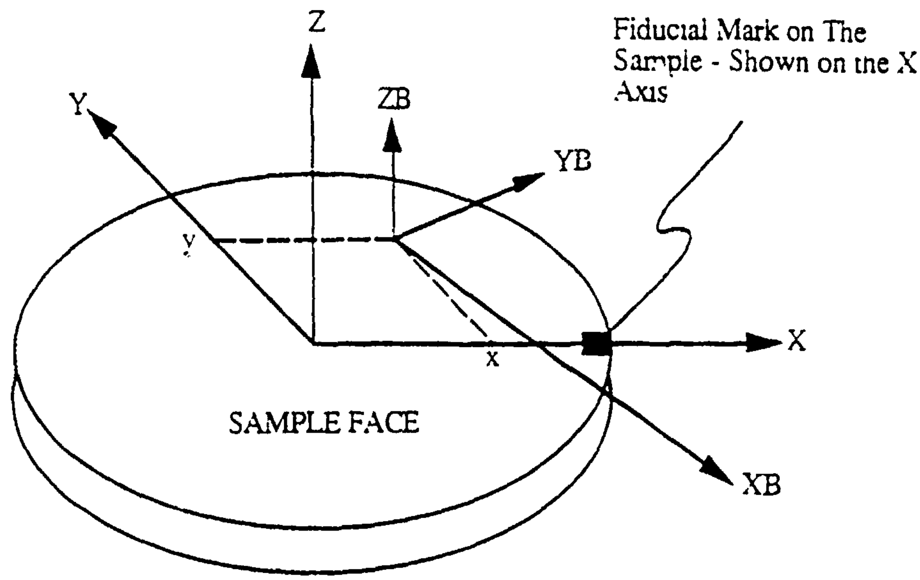
7.6 Measuring the Instrument Signature

Once these initialization steps have been completed the instrument is ready to take data. The first data taken after system installation should be the Instrument Signature. The Instrument Signature is the beam profile of the instrument as measured by sweeping the detector through the focused beam.

By measuring the Instrument Signature the alignment of the instrument is checked, the background optical noise of the instrument is measured and a baseline for comparisons of scatter data is set. The Instrument Signature determines the angular range sample scatter data can be measured. It also forces the measurement of the incident power required for the computations of BSDF to be done. (TMA (Hardware Reference Manual), April 20, 1988; pgs. 28)

8.0 Polarization Geometry

The relationship between the sample (X,Y,Z) and the beam (XB,YB,ZB) coordinate systems is as follows (Figure 6) the Z and ZB axes are always the local normal to the sample face. Locations on the same face are measured in the sample coordinate system. The incident and scatter directions are measured in the beam coordinate system. If the sample fiducial mark is not an X axis mark, the intended value must be indicated on the sample. (ASTM (Standard Practice for Angle Resolved Optical Scatter Measurements on Specular and Diffuse Surfaces), pg. 12)



Note 1: The X-Y zero position on the sample face is assumed to be the geometric center of the sample.

Note 2: The fiducial mark can be on the edge or back of the sample.

Figure 6 · Relationship between sample and beam coordinate systems

9.0 Scatter Viewed As Diffraction

An important fact is that scatter may be viewed as diffraction. Diffraction theory predicts the intensity and location of light diffracted from an input specular beam out into the sphere surrounding the diffracting component. The grating equation is a direct result of diffraction theory and is used to define the location of diffracted (scattered) light. It is useful to define the grating equation in terms of our geometry at this point.

Plane of Incidence

$$\text{Sin}\,\theta_s = \text{Sin}\,\theta_i + N\,\lambda/A$$

$$N = 0, \pm 1, \pm 2$$

Full Hemisphere

Using $N = \pm 1$ and defining $1/A = f = (f_x{}^2 + f_y{}^2)^{1/2}$

Grating propagates in the θ direction

$\sin \theta_s \cos \theta_s = \sin \theta_i \pm f_x\lambda$

$\sin \theta_s \sin \theta_s = f_y\lambda$

The grating equation defines diffraction (scatter) location only; so far, nothing has been said about intensity. In general, the larger surface defects are the larger the scatter will be. (Stover, John C.; 1989, P. 1-4)

10.0 Definition of Terms

In order to fully understand the meaning of scatter and its impact on the measuring of optical scatter it is necessary to comprehend the meaning and context of terms.

10.1 Total Integrated Scatter (TIS)

The instrument gathers a large fraction of the light scattered into the hemisphere in front of the sample and focuses this light onto a single detector. The detector reading is normalized by the reflected or transmitted specular light and this ratio is referred to as the "TIS".

Davies Paper was published in 1954. It concerns itself with radar. It gives the following formula for TIS:

$$TIS = \frac{\text{Reflected Scattered Light}}{\text{Reflected Specular Light}}$$

This equation is derived from:

$$TIS = 1 - e^{\left(\frac{4\pi\delta}{\lambda}\right)^2} \cong \left(\frac{4\pi\delta}{\lambda}\right)^2 \text{ for } \left(\frac{4\pi\delta}{\lambda}\right)^2 \ll 1$$

Where λ is the light wavelength and δ is the root mean square (rms) roughness. (Stover, John C., 1989, P. 2-1)

Bennett and Porteus built an Optical TIS Scatterometer in 1961. They used Davies result. This scatterometer denotes the start of optical scatter measurement as a real source of metrology information. (Stover, John C.; 1989, P. 2-2)

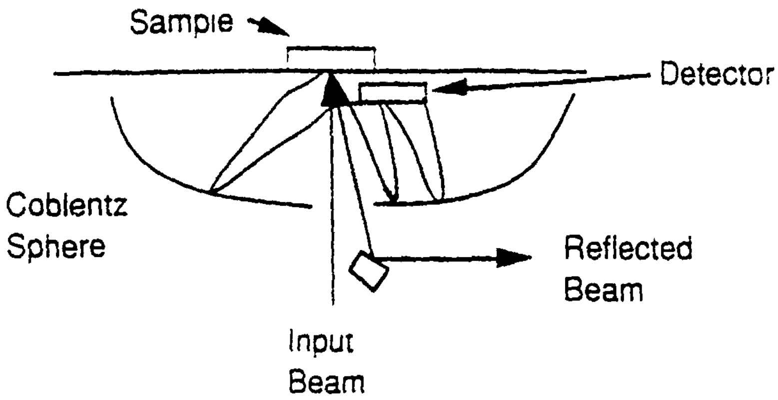


Figure 7 TIS Instrument

Advantages: •Relatively Cheap
•Fast
•Repeatable

Problems: •Detector reflection losses = $f\theta_i$
•$\cos\theta_s \sim 1$ is assumed

Present Use: •Reflection samples
•Transmission samples
•Raster scans
•$\theta_i > 0$

10.2 Bidirectional Distribution Functions (BSDF/BRDF/BTDF)

Measurement of light scattered as a function of an angle gives additional information. BRDF was defined in its present notation by Nicodemus in 1970 and is used to describe the scattering properties of optics. It can be defined for reflecting (BRDF) or transmitting (BTDF) optics. The BRDF is defined as

$$\mathrm{BRDF} \equiv F \equiv \frac{dP_s/\omega_s}{P_i \cos\theta_s}$$

Where: dP_S = power scattered in the θ_s, $\varnothing_s$ direction through $d\omega_s$
$d\omega_s$ = the solid angle containing dP_S
Pi = the incident power

A Lambertian surface exhibits a constant BRDF. Lambertian surfaces are rough and do not meet the smooth surface criteria for TIS δ calculations. (Stover. John C.; 1989. P. 2-3)

Thus if BRDF is known, the scattered power through any aperture. $d\omega_s$, is easily found for any input P_i. A slightly different form of the BRDF is often used and is referred to as "cosine corrected".

$$\mathrm{BRDF} \equiv \frac{dP_s/\omega_s}{P_i}$$

10.3 Instrument Signature

Instrument signature, sometimes called instrument profile, refers to the scatter in a BRDF measurement that is caused by the instrument itself. The signature is usually confined to a region within a few degrees of specular and is caused by:

Scatter in the instrument optics

Specular light reflected off the detector and back onto the sample space

Ghost reflections in the instrument

Limitations on the focussed spot size due to diffraction and aberrations

(Stover. John C.; 1989, P. 2-7)

11.0 Scatterometer Components

A scatterometer is made up of many different components. In order to fully understand how a scatterometer works it is necessary to know what the parts of a scatterometer are.

11.1 Laser Sources and Optics

Coherent light is not required - the laser is just a very convenient light source

The first spatial filter:

- Removes scatter
- Converts beam wander to beam power variations

Chopped light / lock in electronics

Monitor beam power

Polarizers and ND Filters

Second spatial filter removes scatter

Final Focusing Element:

- Determines sample spot size
- Determines focused spot size

• Strong contributor to signature

11.2 Sample Holders

A sample holder can be very simple to very complex. As many as seven degrees of mechanical freedom are possible: θ_i, fine tilt, out of plane tilt, α, x, y, z.

11.3 Detectors (Stover, John C.; 1989, P. 3-2)

Below are listed some types and different features of some detectors.

Types

Si	$.25\mu$ -- 1.1μ
Ge	$.5\mu$ -- 1.9μ
HgCdTe	2μ -- 13μ
InAs	1μ -- 5.5μ
PMT's	Visible/Near IR

Important Features

- Sensitivity
- Dynamic Range
- Low Noise

Housing

- Limited Field of View
- Programmable Low Noise Pre-Amp
- Variable Apertures
- Y Motion
- θ_s Motion
- Tilt Adjust
- BP Filter, Diffuser

11.4 The Computer System (Stover, John C.; 1989, P. 3-2)

The computer system is made up of many different parts. Below is a listing of most of these elements.

Control of Motorized Axes

- "Manual" Control
- "Automatic" Control

Control of Programmable Electronics

- Pre-Amp Gains
- Lock in Gains

- Detector Bias

Control of Beam Devices

- Shutters
- Turning Mirrors
- Apertures
- ND Filters

Control of Data Collection

- Set-up File
- Real Time Data Presentation
- Data Storage
- Data Delivery

Data Presentation and Analysis

- BRDF, BTDF, BSDF
- Log-Log, Log-Linear, Linear-Log, Linear-Linear
- Comparison
- Surface Statistics
- Scatter Predictions - θ_i, λ
- Hard Copies

12.0 Experiments and Results

It is necessary to show just what the workhorse scatterometer at RADC can do through the use of completed experiments. The experiments on the following pages show some of the many capabilities that the workhorse scatterometer has.

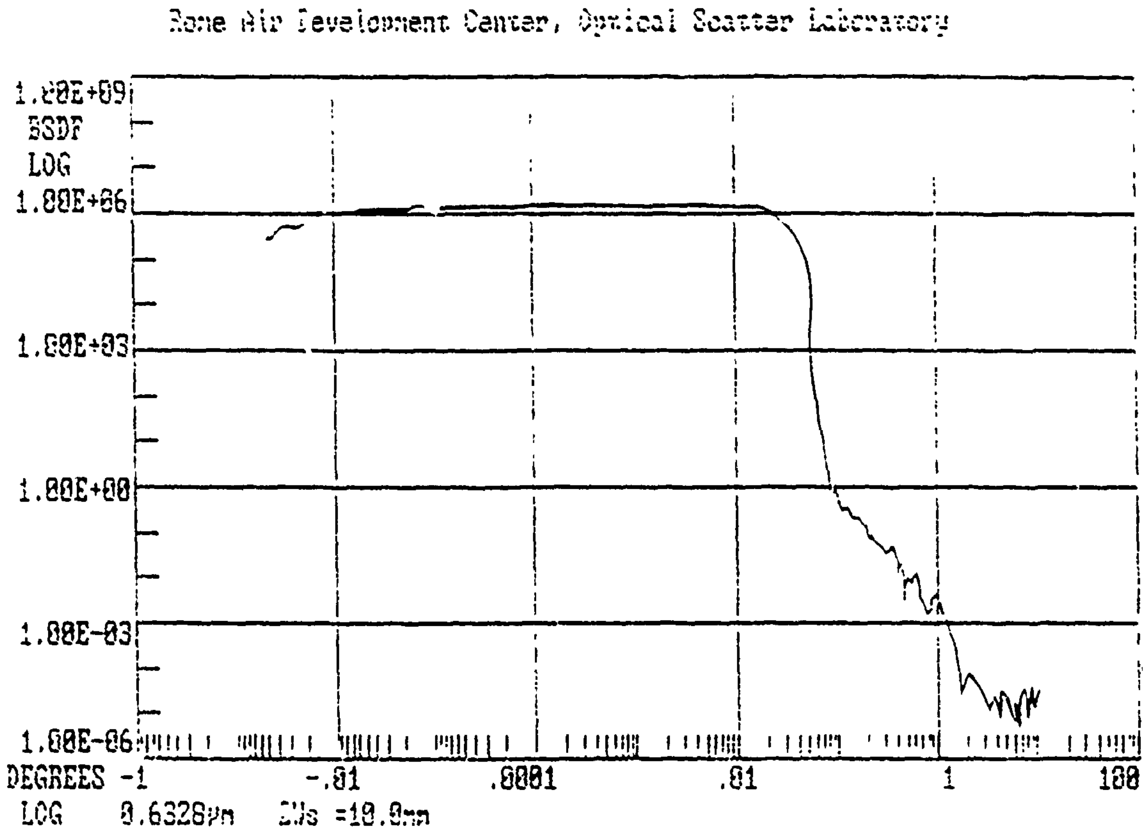


Figure 8: Normal Daily Signature

A system signature must be taken on a daily basis or before any measurements are taken. A system signature shows the amount of scatter present in the instrument for the day. This is used as the baseline for the day.

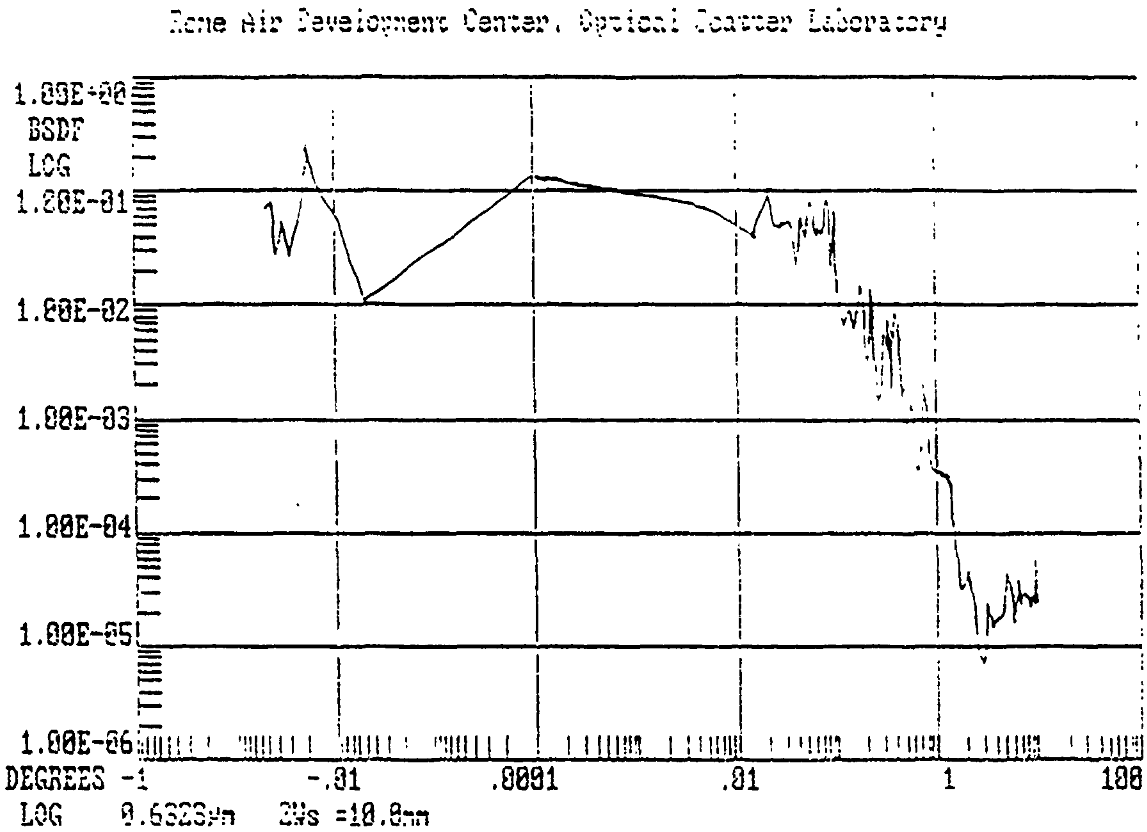


Figure 9: Signature Taken .5° Off Of Specular

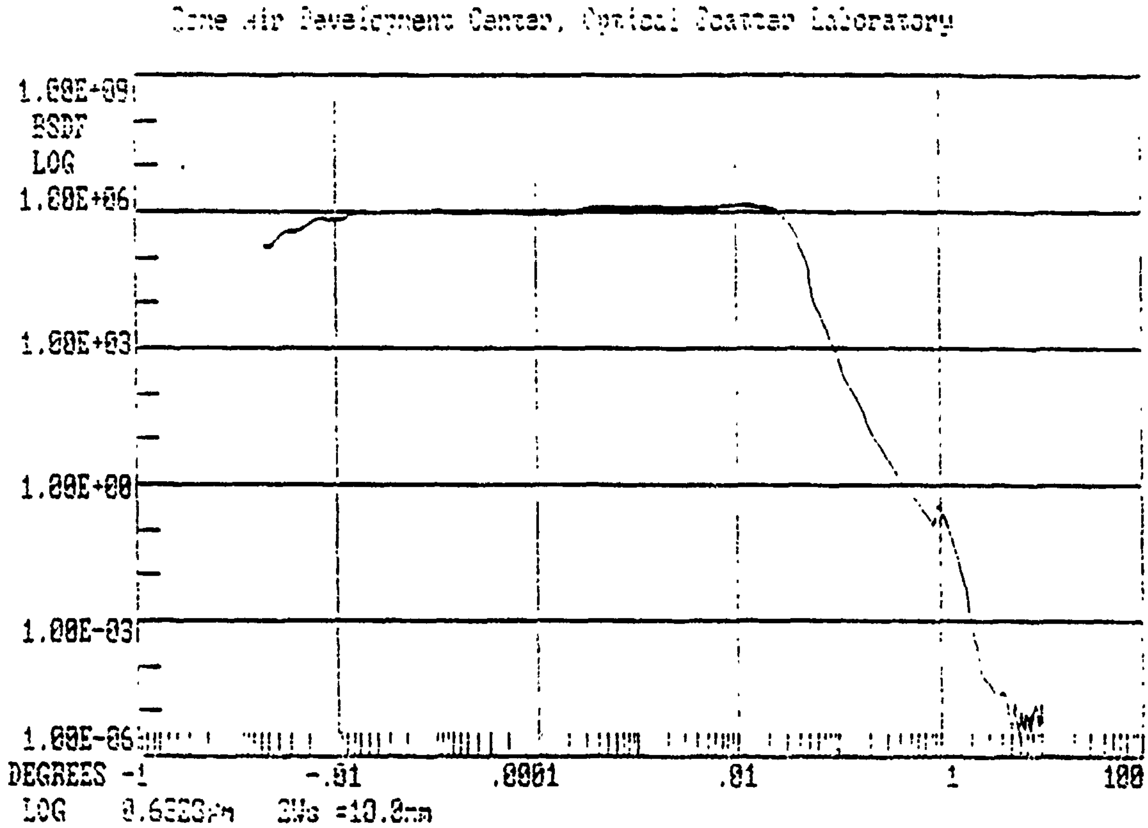


Figure 10: Signature Taken With An Iris Diameter of .54"

This graph demonstrates how an iris acts as another noise parameter in the system and thus causes the signal to fall off more rapidly.

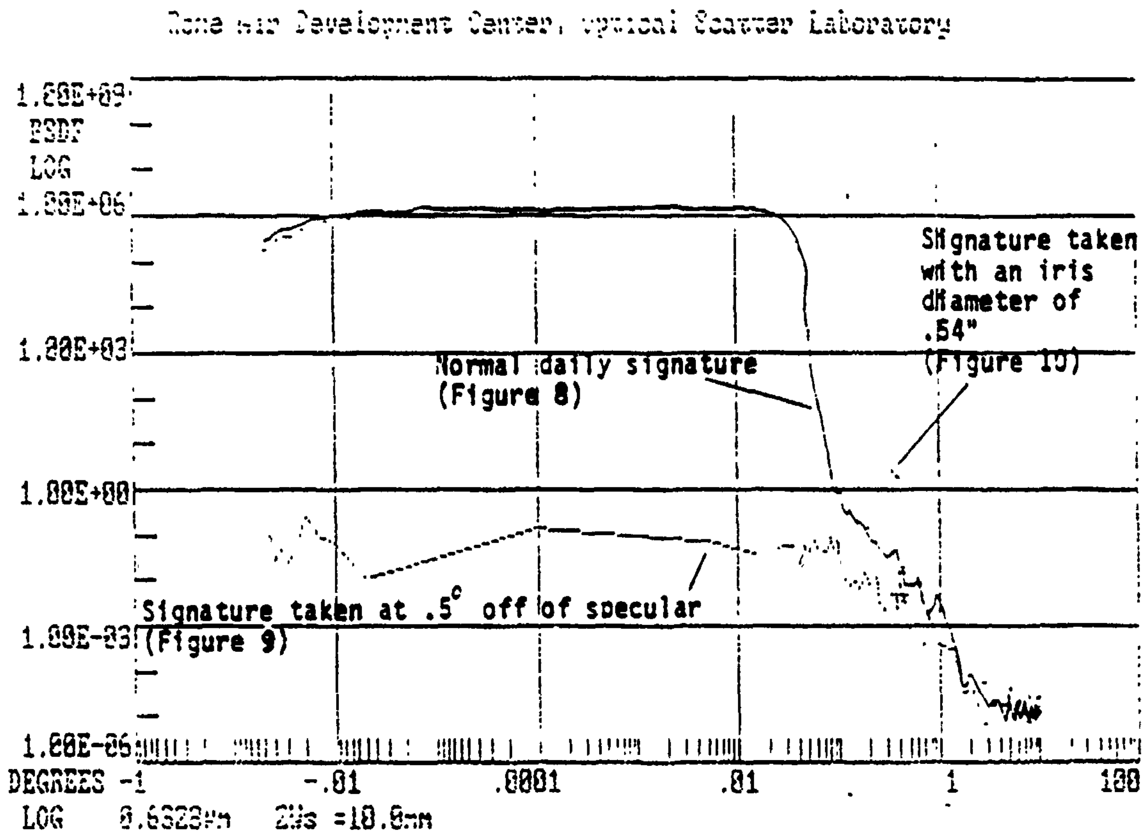


Figure 11: Comparison Graph

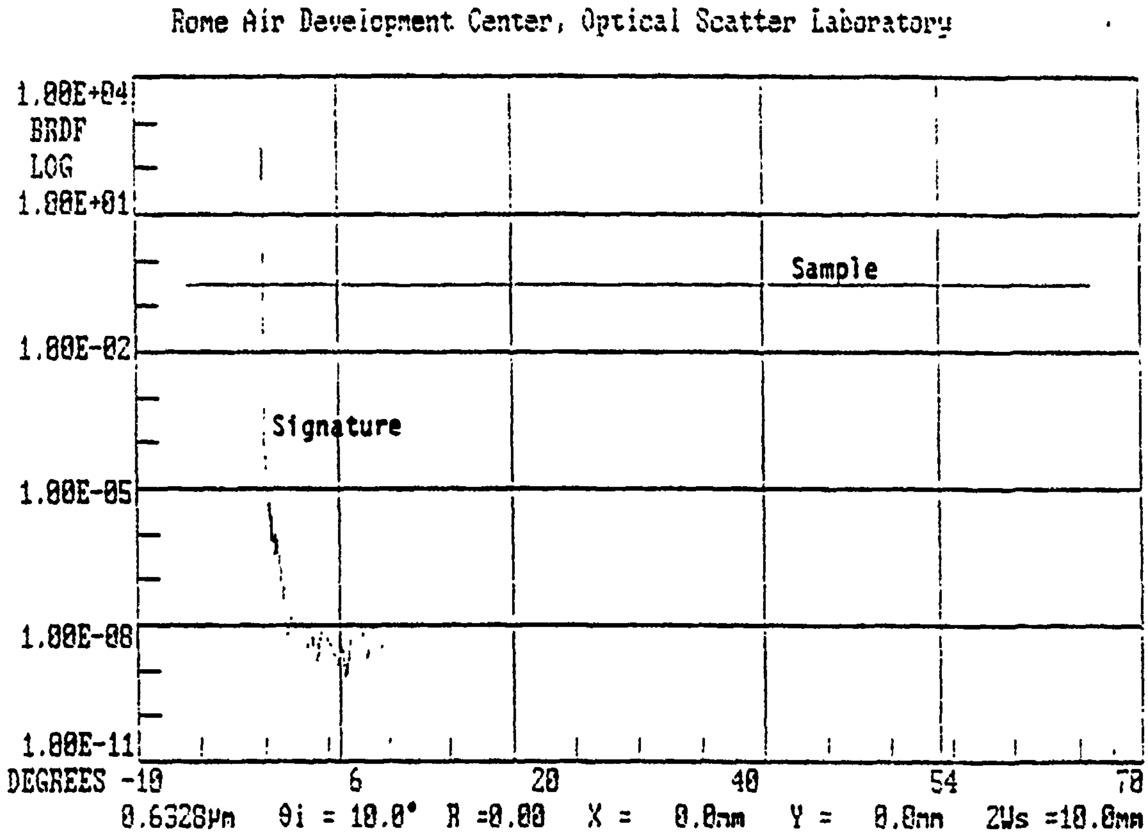


Figure 12: White Diffuse Sample Taken Near Specular

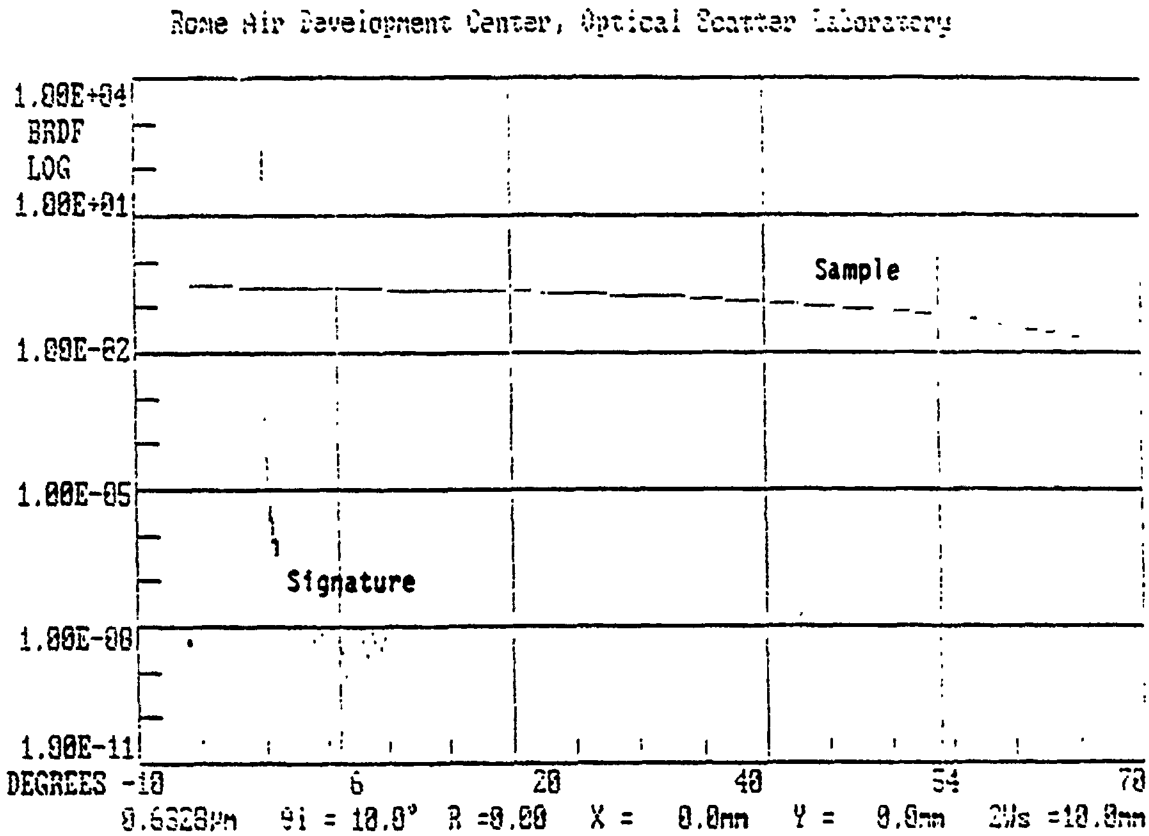


Figure 13: White Diffuse Sample Moved Forward From Center Of Rotation 5mm

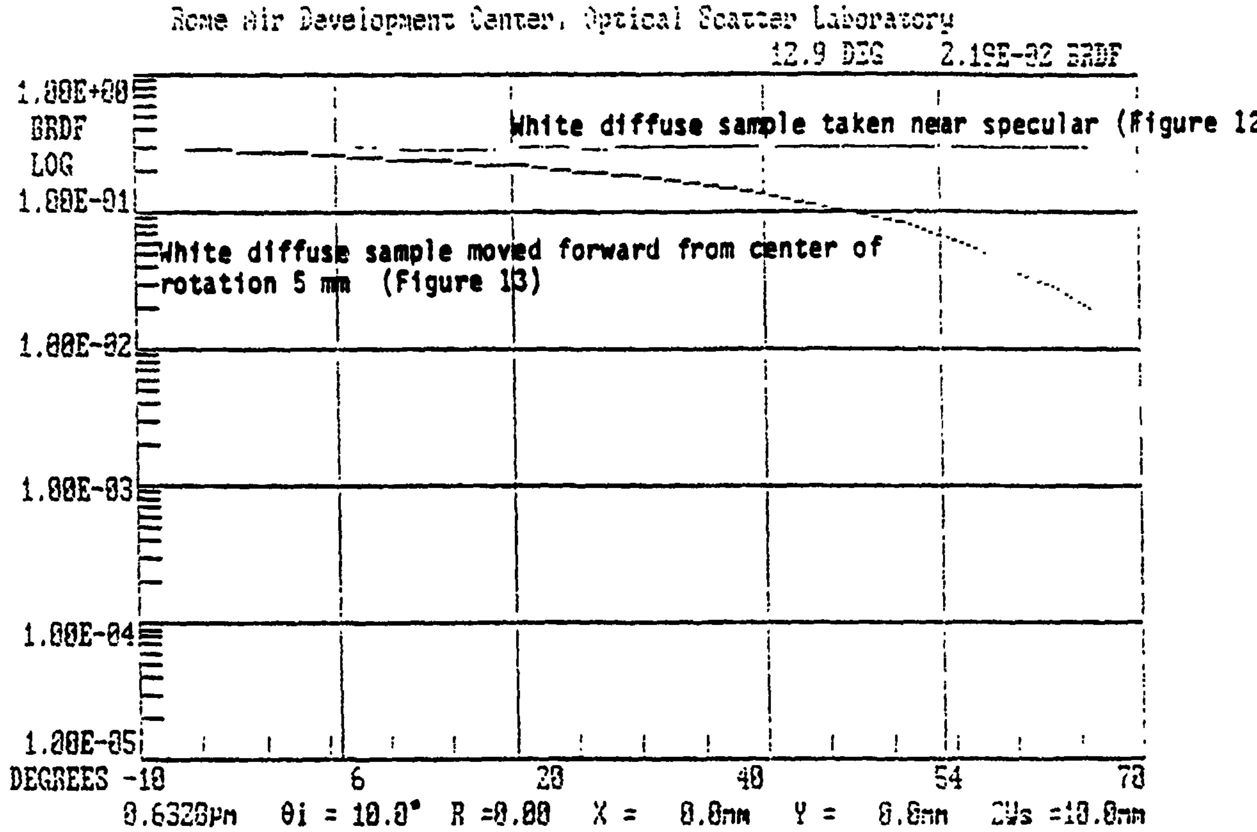


Figure 14: Comparison Graph

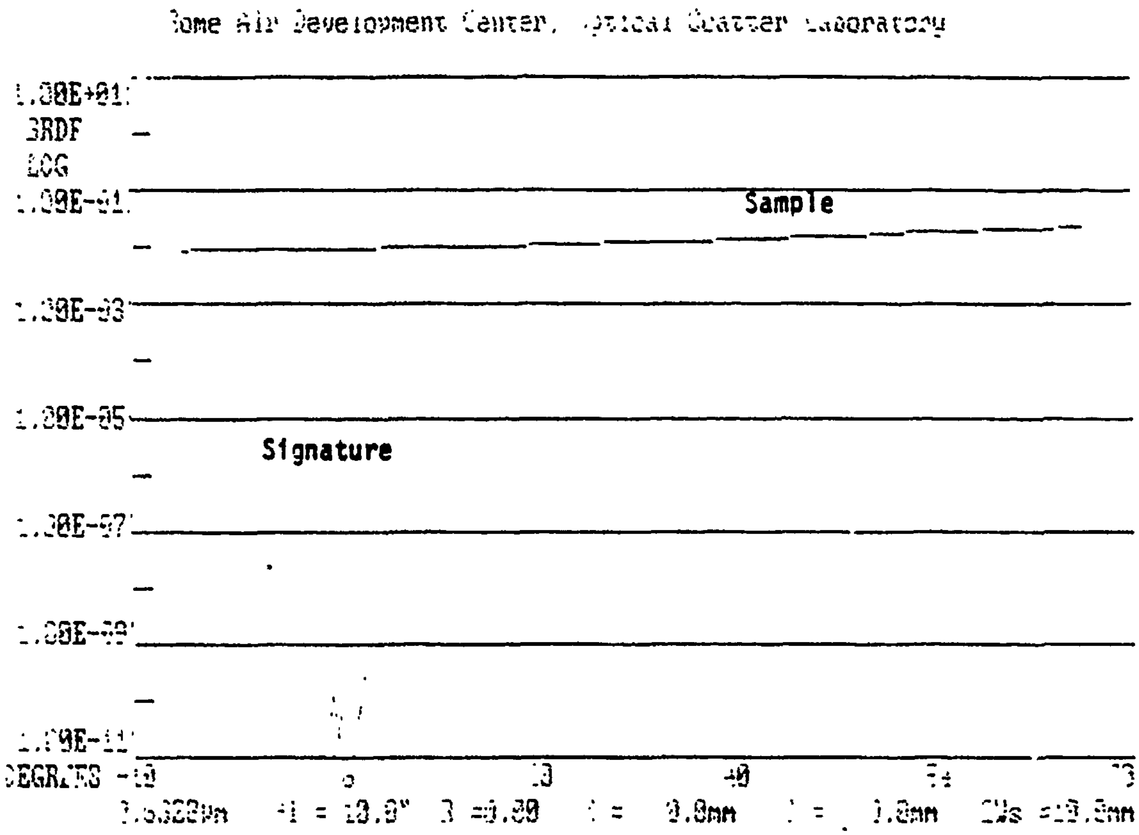


Figure 15: Black Diffuse Sample Taken Near Specular

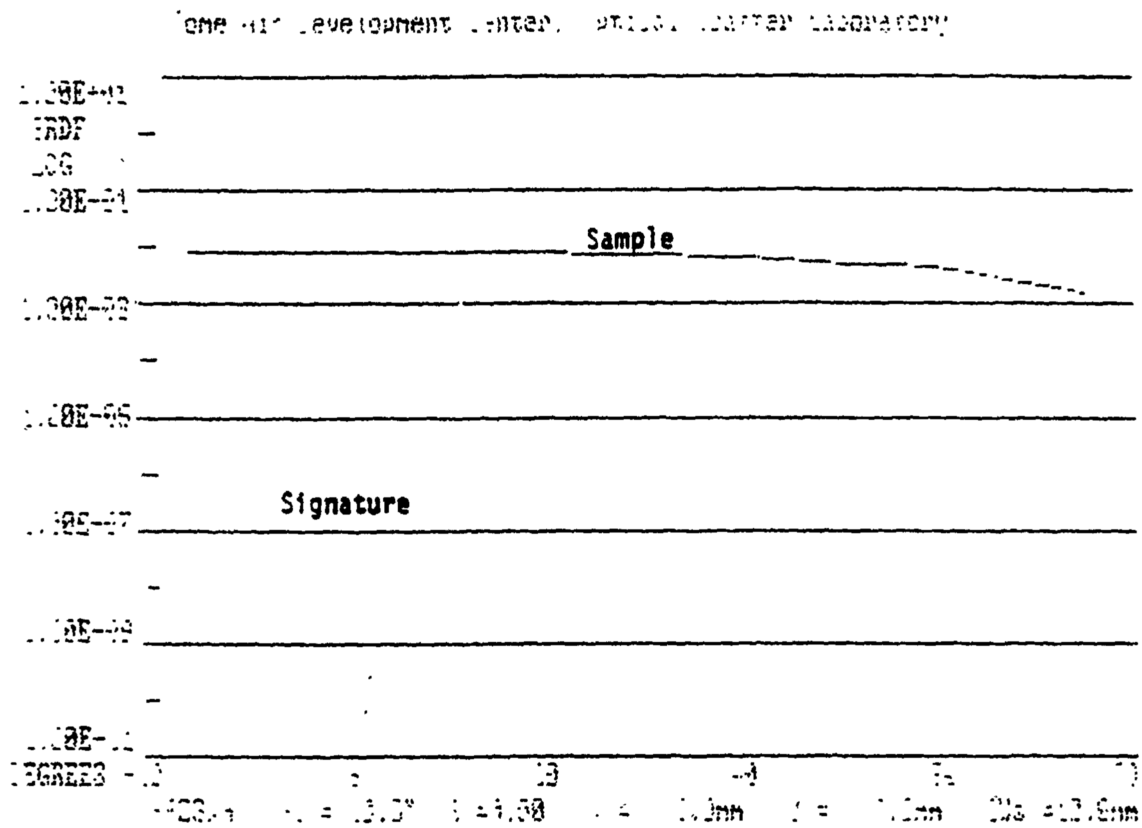


Figure 15: Black Diffuse Sample Moved Forward From Center Of Rotation 5mm

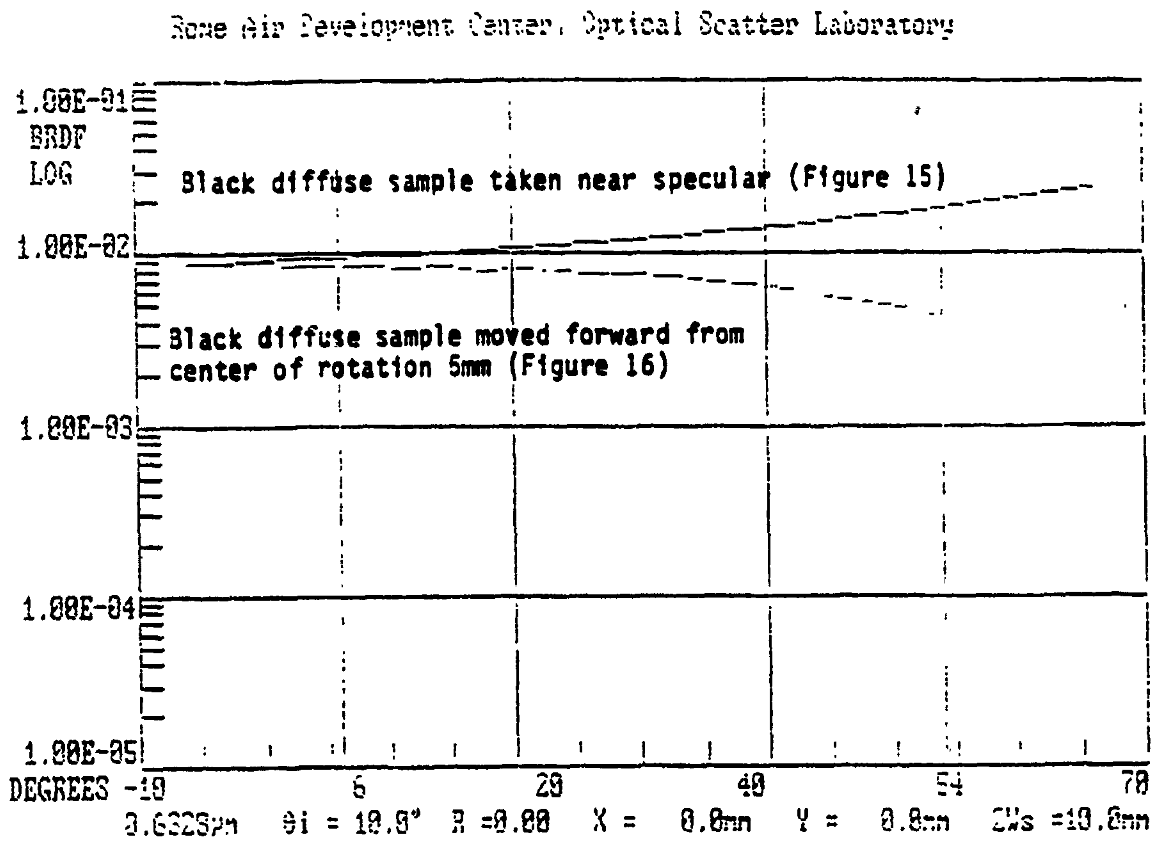


Figure 17: Comparison Graph

RECOMMENDATIONS

After reviewing some aspects of the scatterometer and problems that it has, the writers of this paper have the following recommendations for making the scatterometer at RADC into a more precise instrument:

- Permanent beam enclosures around the table, and
- A clean room environment.

Both of these simple, but yet important aspects can eliminate a major portion of dust particles that cause scatter. Therefore, if these two simple recommendations are initiated the workhorse scatterometer at RADC will greatly become a much more precise instrument that it is presently.

REFERENCES

Sliney, David and Wolbarsht, Myron; 1980.

TMA (Hardware Reference Manual) April 20, 1985.

ASTM (Standard Practice for Angle Resolved Optical Scatter Measurements on Specular and Diffuse Surfaces).

Stover, John C. (Optical Scatter); 1989.

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GLOSSARY

Diffuse Reflections: Scattering at all angles from the point of reflection.

Laser Source Radiance: The beam intensity.

Natural Aversion Response Time: The time for a human to blink.

NdYAG: Neodymium Yitrium Aluminum Garnet

INDEX

Mark Anania

Final Report Number 96

No Report Submitted

RADAR RANGE EQUATION
AND
RADAR DESIGN AND SIMULATION

Bridget M. Berdiuk

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Bill Gavin	John McNamara

I would also like to thank everyone else in OCDS with whom I worked this summer.

INTRODUCTION

Radar systems design is a complicated process that requires knowledge of all aspects of radar principles. It is important to know the effect of electromagnetic (EM) propagation through the atmosphere, including losses due to the transmission of EM waves, antenna characteristics, and the effect of EM waves scattering off of a target. The receiver characteristics, including signal-to-noise ratio and receiver noise bandwidth, are also important areas that must be considered in any radar design.

The fundamental relationship between the factors that determine a radar design is given by the following mathematical expression:

$$R^4 = \frac{\hat{P}_T G_T L_T A_e L_R L_P L_a L_c L_s \sigma_t \; {}^1}{(4\pi)^2 K T_s B_N (S/N)} \qquad \text{(Eq. 1)}^1$$

This expression is known as the radar range equation. The particular form of Eq.(1) is known as the detection form of the radar range equation.

A complete radar system or sub-component can be designed based on the derivation of Eq.(1). This paper describes the process of designing a phased array antenna given specific radar parameters.

Problem:

Design a phased array radar antenna given the following parameters:

- Ground search radar
- Phased array radar
- Able to detect a 1 m^2 radar cross section target

(cont.)

at 250 nautical miles (nmi).

- Beamwidth of 1.00°
- Frequency between UHF - C band
- Length of aperture limited to 2 - 10 m.
- Peak transmitting power of 1 megawatt (mw).

After working through the design process, the derived antenna parameters were used to simulate the antenna radiation pattern with a software package called the Parametric Antenna Analysis Subsystem (PAAS). PAAS is a generic, flexible design tool that provides rapid simulation of antenna radiation patterns.

[1] Radar Design Principles, Nathanson, p. 50, fig.(2-6)

DEFINITIONS OF VARIABLES
IN THE RADAR RANGE EQUATION

The following is a description of the variables that are used in the radar range equation. The indicated values are either estimates for the variable or are given parameters.

(R^4) (250 nmi)^4

Range : the maximum distance at which a target's echo is strong enough to be detected.

(A_e)

Effective aperture : The size of the antenna's frontal area multiplied by the efficiency factor. The efficiency factor for a uniformly illuminated aperture would be (1). However, uniform illumination is practically impossible, so realistically the efficiency factor ranges between (.4) to (.7).

(L_T) (2 dB)*

Transmitting power loss : the losses between the transmitted output and free space. These losses include those of duplexers, waveguide or coax, radomes, and any other losses which do not affect the beam width of the radar.

(G_T)

Transmitting power gain : the ratio of the power of the radiation in a given direction to the power of the radiation that would be produced in the same direction, if the same output power was radiated isotropically.

($\hat{P}_T$) (1 mw)

Peak transmitting power : the output power during transmitting. It determines the voltage that must be supplied to the transmitter.

(cont.)

(L_R) (2 dB)*

<u>Receiver power loss</u> : the losses between free space and receiver input. Like transmitting losses, these losses include duplexers, waveguide or coax, radomes, and any other losses which do not affect the beamwidth of the radar.

(B_N) $[1/(6*10^{-6}\ s.)]$*

<u>Noise bandwidth of receiver</u> : the frequency response width of the receiver. B_N directly affects the noise level in the receiver output.

(S/N) (13 dB)*

<u>Signal-to-noise ratio</u> : an acceptable value by which the desired signal exceeds the root mean square (rms) noise level overall.

(T_s) (290 K) *

<u>System noise temperature</u> : the noise temperature of the system, including antenna temperature, receiver noise, and environmental effects.

(L_P) (1.6 dB)*

<u>Beamshape loss</u> : the additional signal strength required to make up for the reduced amplitude of pulses received when the beam axis moves off the target.

<u>Scanning loss</u> : the loss that occurs when antenna position is changed during the interval in which the signal travels from the antenna to the target and back.

<u>Pattern factor losses</u> : these losses depend on reflections off of land or sea, and these reflections may add or subtract to the main beam antenna gain.

(L_A) (2.5 dB)*

<u>Two-way pattern absorption and propagation losses</u> : these losses account for the effects of a target not being in the main beam of the vertical antenna pattern, and the possibility of non-free space

(cont.)

wave propagation, as well as atmospheric absorption.

(L_c) (.9 dB)*

Collapsing loss : a signal detectability loss that results from excess noise present due to collapsing. The radar data is visually displayed in such a way that some of the resolution cells are overlapped in one or more of the three directions.

(L_s) (.9 dB)*

Signal processing loss : this loss is based on the spectrum and distribution of clutter returns.

(σ_t) (1 m^2)

Target cross-section : the minimal cross-sectional area of a target that can be detected.

(K) ($1.38 * 10^{-23}$)

Boltzmann's constant

* After reading several references and speaking with many experienced, knowledgeable persons, I feel that I have given reasonable estimates for the values listed above.

CALCULATIONS

The following are calculations made to derive the antenna parameters:

(R^4)

$$(250\ \text{nmi})(1.852\ \text{km/nmi}) = 463\ \text{km}$$
$$(463\ \text{km})(1{,}000\ \text{m/km}) = 463{,}000\ \text{m}$$
$$(463{,}000\ \text{m})^4 = 4.595406816 * 10^{22}\ \text{m}$$

$$10\ [(\log 4.595406816) + (\log 10^{22})] = n\ \text{dB}$$
$$10\ (0.662323964 + 22) = n\ \text{dB}$$
$$10\ (22.662323964) = n\ \text{dB}$$
$$4.595406816 * 10^{22} = 226.62323964\ \text{dB}$$

($\hat{P}_T$)

$$(1\ \text{mw})(1{,}000{,}000\ \text{w/mw}) = 1{,}000{,}000\ \text{w}$$

$$10\ \log 1{,}000{,}000 = n\ \text{dB}$$
$$10\ (6) = n\ \text{dB}$$
$$1{,}000{,}000 = 60\ \text{dB}$$

$(4\pi)^2$

$$(4\pi)^2 = (12.56637061)^2$$
$$(12.56637061)^2 = 157.9136703$$

$$10\ \log 157.9136703 = n\ \text{dB}$$
$$10\ (2.198419728) = n\ \text{dB}$$
$$157.9136703 = 21.98419728\ \text{dB}$$

(cont.)

(B_N)

$$(1/6 * 10^{-6} \mu m) = 166,666.7 \text{ Hz}$$

$$10 \log 166,666.7 = n \text{ dB}$$

$$10 (5.221848836) = n \text{ dB}$$

$$166,666.7 = 52.21848836 \text{ dB}$$

(T_s)

$$10 \log 290 = n \text{ dB}$$

$$10 (2.462397998) = n \text{ dB}$$

$$290 = 24.62397998 \text{ dB}$$

(K)

$$10 [(\log 1.38) + (\log 10^{-23})] = n \text{ dB}$$

$$10 (0.139879086 + -23) = n \text{ dB}$$

$$10 (-22.86012091) = n \text{ dB}$$

$$1.38 * 10^{-23} = -228.6012091 \text{ dB}$$

(σ_t)

$$10 \log 1 = n \text{ dB}$$

$$10 (0) = n \text{ dB}$$

$$1 \text{ m}^2 = 0 \text{ dB}$$

RADAR RANGE EQUATION
CALCULATION WORK SHEET

The purpose of the chart on the following page is to display the parameters of the equation and their decibel values in an organized manner for calculation.

In the two right-most columns, labeled "PLUS (+)" and "MINUS (-)", the negative and positive values are placed accordingly. It is then possible to add up the values of each column, subtract their totals, and derive a value for the two unknowns of the equation, G_T and A_e.

RADAR RANGE EQUATION CALCULATION WORK SHEET

RANGE FACTORS		DECIBEL VALUES	PLUS (+)	MINUS (-)
R^4	$4.595406816 * 10^{22}$ m	226.62323964		226.62323964
P_T	1 mw	60	60	
G_T	?	?	?	
L_T	2 dB	2		2
A_e	?	?	?	
L_R	2 dB	2		2
L_P	1.6 dB	1.6		1.6
L_a	2.5 dB	2.5		2.5
L_c	.9 dB	.9		.9
L_s	.9 dB	.9		.9
σ_t	1 m^2	0	0	
$(4\pi)^2$	157.9136704	21.98419728		21.98419728
K	$1.38 * 10^{-23}$	228.60120913	228.60120913	
T_s	290 K	24.62397998		24.62397998
B_N	166,666.7 Hz	52.21848836		52.21848836
S/N	13 dB	13		13
			283.60120913	348.3499052
			$G_T + A_e =$ 59.7486961	

SOLVING FOR

G_T and A_e

$$G_T + A_e = 59.7486961 \text{ dB}$$

$$10 \log n = 59.7486961 \text{ dB}$$

$$\log n = 5.97486961 \text{ dB}$$

$$\log^{-1} 5.97486961 \text{ dB} = 943{,}777.4796$$

$$(G_T) * (A_e) = 943{,}777.4796$$

$$\frac{(4\pi A_e)^1}{\lambda^2} * (A_e) = 943{,}777.4796$$

At this point, a frequency was needed to solve for wavelength, (λ). A frequency of 1.5 GHz (L band), $\lambda = .2$ m, was chosen, as the use of L-band is typical for search radars.

$$\frac{\lambda^2 * 4\pi A_e^2}{\lambda^2} = 943{,}777.4796 * (.04 \text{ m})$$

$$4\pi A_e^2 = 37{,}751.09918 \text{ m}$$

$$\frac{4\pi A_e^2}{4\pi} = \frac{37{,}751.09918 \text{ m}}{12.56637061}$$

$$A_e^2 = 3004.137022 \text{ m}$$

$$A_e = 54.81000841 \text{ m}^2$$

efficiency factor = .55

Length (L) of aperture = square root of (A_e/.55)

L = square root of (99.65456075)

L = 9.982713095 m

(cont.)

Solving for 1.00° beamwidth:

$$\theta_{3\ dB} = (.88\ \text{rad.})(\lambda)/L\ ^{*}$$
$$\theta_{3\ dB} = (.88\ \text{rad.})(.2\ \text{m})/9.982713095\ \text{m}$$
$$\theta_{3\ dB} = (.176\ \text{rad./m})/9.982713095\ \text{m}$$
$$\theta_{3\ dB} = .017630477\ \text{rad.}$$
$$\theta_{3\ dB} = .017630477\ \text{rad.} * 57.3^{\circ}/\text{rad.}$$
$$\theta_{3\ dB} = 1.010226369^{\circ}$$

1.010226369° exceeded the desired 1.00° beamwidth, so using an iterative approach, different values were substituted for λ, until a 1.00° beamwidth was acheived. The calculations are shown on the following page.

[1] Nathanson, F.E., Radar Design Principles, McGraw-Hill Book Company, New York, 1969, p. 41

[*] Stimson, G.W., Introduction to Airborne Radar, Hughes Aircraft Company, California, 1983, p. 136

SOLVING FOR

G_T and A_e

(cont.)

$$(G_T) * (A_e) = 943{,}777.4796$$

$$\frac{(4\pi A_e)}{\lambda^2} * (A_e) = 943{,}777.4796$$

$$\frac{\lambda^2 * (4\pi A_e^2)}{\lambda^2} = 943{,}777.4796 * {}^2$$

At this point, a wavelength (λ) of 19.7009 cm was chosen, and a frequency of 1.52273071 GHz.

$$\frac{\lambda^2 * (4\pi A_e^2)}{\lambda^2} = 943{,}777.4796 * (.038812546\ \text{m})$$

$$\frac{4\pi A_e^2}{4\pi} = \frac{36{,}630.40692\ \text{m}}{12.56637061}$$

$$A_e^2 = 2{,}914.955165\ \text{m}$$

$$A_e = 53.99032474\ \text{m}^2$$

efficiency factor = .55

L = square root of (A_e/.55)

L = square root of (98.1642268)

L = 9.90778617 m

(cont.)

Solving for beamwidth:

$$\theta_{3\ dB} = (.88\ \text{rad.})(\lambda)/L$$
$$\theta_{3\ dB} = (.88\ \text{rad.})(.197009\ \text{m})/9.90778617\ \text{m}$$
$$\theta_{3\ dB} = (.17336792\ \text{rad./m})/9.90778617\ \text{m}$$
$$\theta_{3\ dB} = .017498149\ \text{rad.}$$
$$\theta_{3\ dB} = .017498149\ \text{rad.} * 57.3^\circ/\text{rad.}$$
$$= 1.002643945^\circ$$

With a wavelength (λ) of 19.7009 cm and a frequency of 1.52273071 GHz, a beamwidth of 1.00° was acheived. Solving for G_T:

$$G_T = \frac{4\pi A_e}{\lambda^2}$$
$$A_e = 53.99032474\ \text{m}^2$$
$$G_T = \frac{4\pi(53.99032474\ \text{m}^2}{.038812546\ \text{m}}$$
$$G_T = \frac{12.56637061 * (53.99032474\ \text{m}^2)}{.038812546\ \text{m}}$$
$$G_T = \frac{678.46243\ \text{m}}{.038812546\ \text{m}}$$
$$G_T = 17{,}480.49278$$

$$10 \log 17{,}480.49278 = n\ \text{dB}$$
$$10\ (4.242553671) = n\ \text{dB}$$

(cont.)

$$17{,}480.49278 = 42.42553671 \text{ dB}$$

$$A_e = 53.99032474 \text{ m}^2$$

$$10 \log 53.99032474 = n \text{ dB}$$

$$10\,(1.73231594) = n \text{ dB}$$

$$53.99032474 = 17.3231594 \text{ dB}$$

PROOF

Here, the derived parameters are inserted into the radar range equation, and the equation is solved for R^4.

* all numbers are in dB.

$$R^4 = \frac{\hat{P}_T G_T L_T A_e L_R L_P L_a L_c L_s \sigma_t}{(4\pi)^2 K T_s B_N (S/N)}$$

$$(226.62323964) = \frac{(60)+(42.42553671)-(9.9)^{a}+(17.3231594)+(0) \quad =09.8486961}{(21.98419728)-(228.60120913)+(24.62397998)+(52.21848836)+(13) \quad =166.7745435}$$

$$(226.62323964\ \text{dB}) = 109.8486961 - (-166.7745435)$$
$$(226.62323964\ \text{dB}) = 226.62323964\ \text{dB}$$

[a] : the total of all loss values.

SIMULATION
OF
ANTENNA

Using the Parametric Antenna Analysis Subsystem (PAAS) software package, I simulated antenna radiation patterns based on the parameters derived from the radar range equation. Parameters used in programming the simulation were effective aperture of the antenna and operating frequency.

Weighting and beamsteering factors were changed, thus altering the resulting radiation pattern. All parameters, except for the factor(s) being tested, remained constant. Simulations are comparable, thereby allowing the effects each factor being tested had on the radiation pattern to be observed.

A three-dimensional plot and a two-dimensional vertical cut through the mainlobe illustrate the directive gain in decibels (dB) of each simulation. Those simulations that include beamsteering also have a two-dimensional vertical cut displaying the modulus in dB.

Test Case # 1

Purpose: The purpose of this simulation was to determine the antenna radiation pattern resulting from the calculations I had made using the radar range equation. This antenna pattern was used as a nominal case for comparison against the other test cases.

System Description:

Frequency: 1.5227 GHz

Feed: Ideal Space Feed

Weighting: Uniform

Main Array: Square (L = 9.9078 m)

4 Bit Phase Shifters

Rectangular Element Lattice

Element Spacing = .098504 m

No Beamsteering

Input Data:

Table (1) shows the Run File created for use in PAAS.

Output Data:

A.) PLOT3D was used to show the three-dimensional view of the antenna radiation pattern resulting from the simulation (see fig. 1)

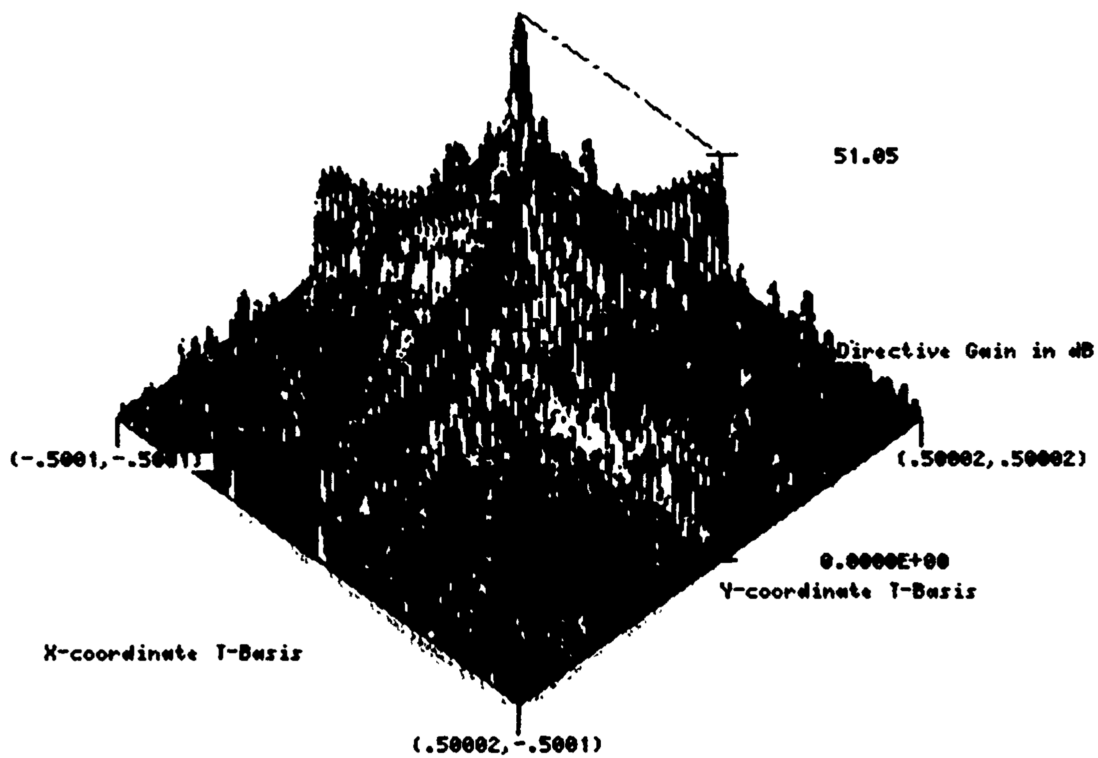
B.) PATCUT was used to show the vertical cut through the mainlobe of the pattern. (see fig. 2)

TABLE (1.)

```
SIMSYS
FINST =   1.5227E+00, FOPER =   1.5227E+00,
$
LATTICE
ILTYPE=            1, COLSPC=   9.8504E-02, ROWSPC=   9.8504E-02,
$
RSHAPE
XWIDTH=   9.9078E+00, YHIGH =   9.9078E+00, WTXRAD=   4.9539E+00, WTYRAD=   4.9539E+00,
$
WITSYS
IWTFLG=            0,
$
SPAFED
XNFEDA=   0.0000E+00, YNFEDA=   0.0000E+00, ZNFEDA=   2.0000E+01, XAFEDA=   0.0000E+00,
YAFEDA=   0.0000E+00, ZAFEDA=   2.0000E+01,
$
PLARY
<
IBSFLG=            0, XBEAMT=   0.0000E+00, YBEAMT=   0.0000E+00, NBITS =            4,
LSBRND=            1, IROFF =            0, ITAPER=            1, DENMAX=   1.0000E+00,
IQ4   =            2,
$
XFORM
<
>
N2    =            9, TXCENT=   0.0000E+00, TYCENT=   0.0000E+00, TXSPAN=   1.0000E+00,
TYSPAN=   1.0000E+00,
$
TCS
IGRDF =            3, IBAUD =         9600, ICAPLB=            2,
$
CLOSER
```

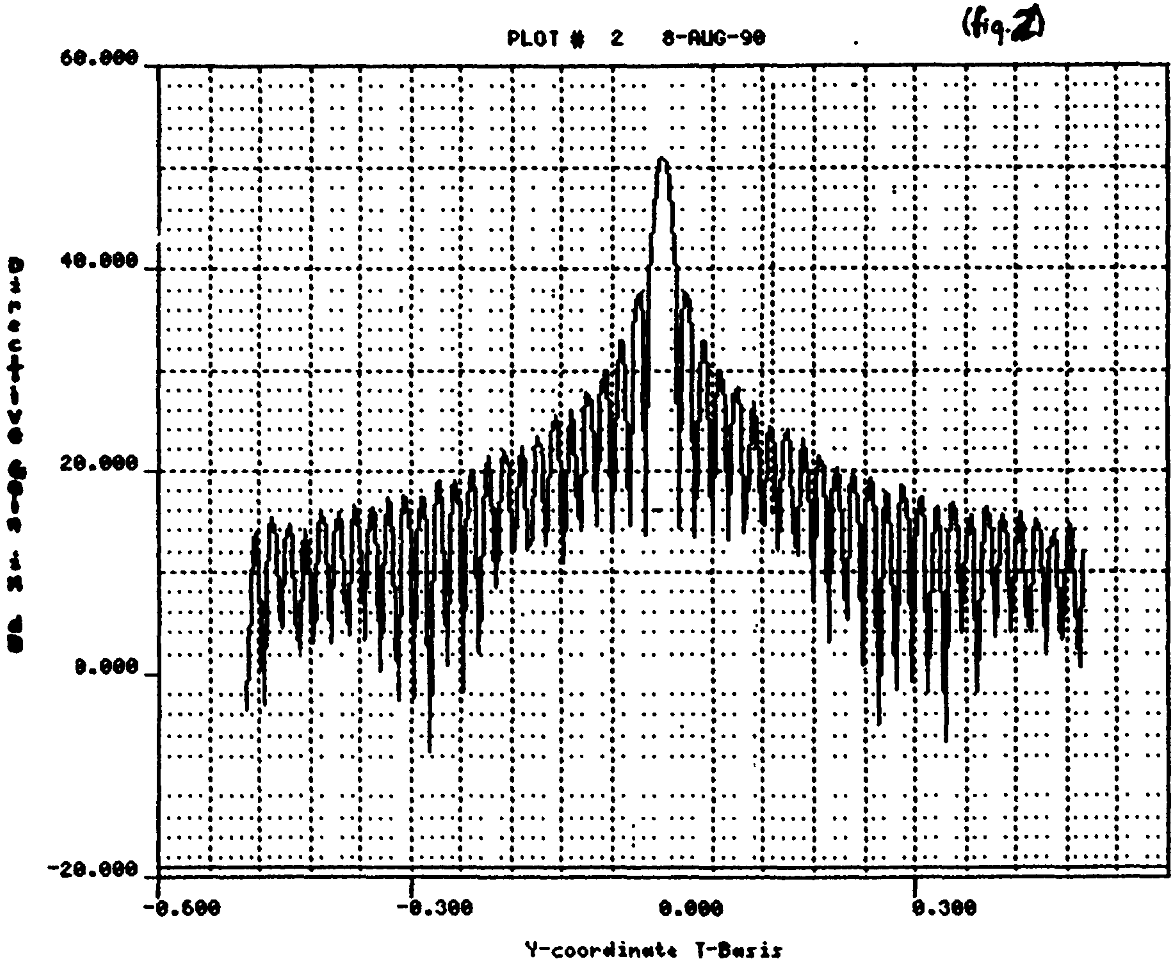
PLOT # 2 8-AUG-90

(fig.1)



Surface Diagram of the Array Factor

The Peak Directive Gain is 51.055dB



Vert Cut (X= 0.00000E+00) thru Array Factor
The Peak Directive Gain (Assumes Non-Zero Radiation
only in the Forward Hemisphere) is 0.51055E+02 dB
OCCURS AT X = 0.00000E+00
OCCURS AT Y = 0.00000E+00

Test Case # 2

Purpose: The purpose of this simulation was to demonstrate the effects of beamsteering on the antenna radiation pattern. The beam was steered 20° off boresight in the direction of the positive Y-axis. All other parameters remained the same.

System Description:

Frequency: 1.5227 GHz

Feed: Ideal Space Feed

Weighting: Uniform

Main Array: Square (L = 9.9078 m)

4 Bit Phase Shifters

Rectangular Element Lattice

Element Spacing = .098504 m

Beamsteering: XBEAMT = 0.0

YBEAMT = .34202

Input Data:

Table (2) shows the Run File created for use in PAAS.

Output Data:

A.) PLOT3D was used to show the three-dimensional view of the antenna radiation pattern resulting from the simulation. (fig. 3)

B.) PATCUT was used to show the vertical cut through the mainlobe of the pattern. (fig. 4)

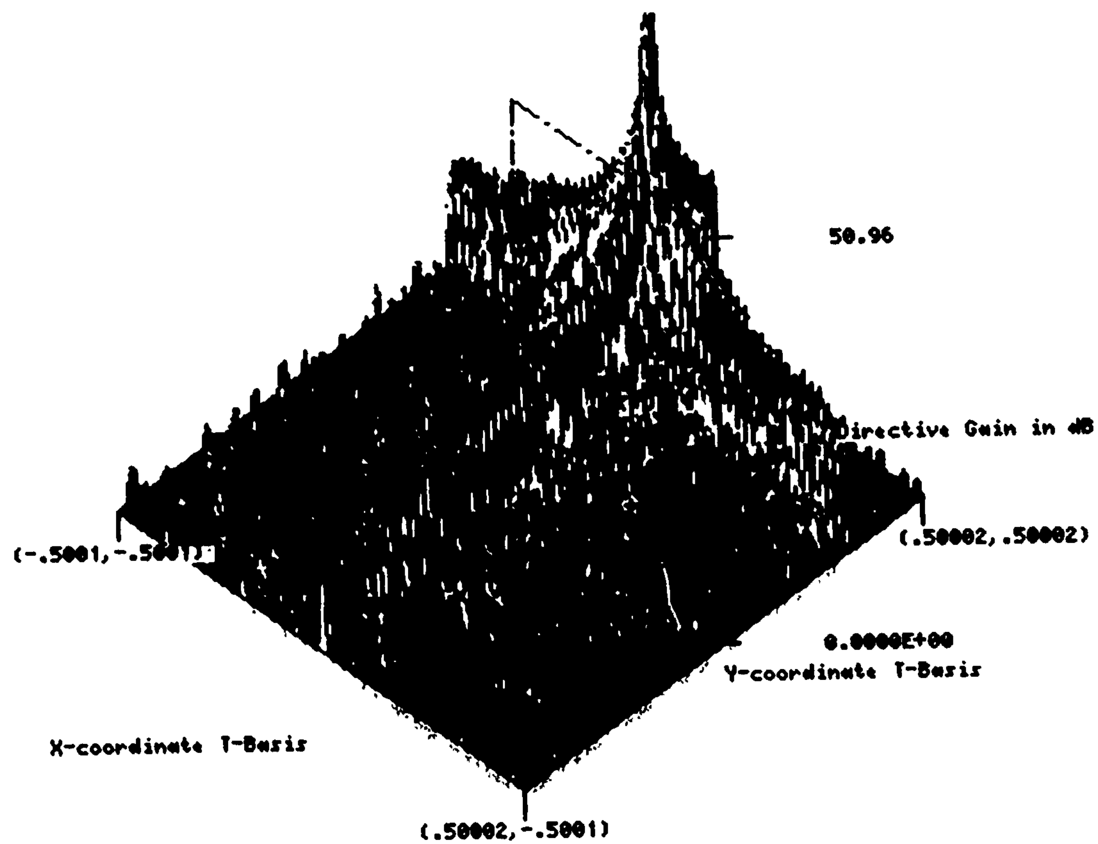
C.) PATCUT was used to show the two-dimensional view of the modulus of uniform weighting in decibels (dB). (fig. 5)

TABLE (2.)

```
SIMSYS
FINST =  1. 5227E+00, FOPER =  1. 5227E+00,
$
LATTICE
ILTYPE=             1, COLSPC=  9. 8504E-02, ROWSPC=  9. 8504E-02,
$
RSHAPE
XWIDTH=  9. 9078E+00, YHIGH =  9. 9078E+00, WTXRAD=  4. 9539E+00, WTYRAD=  4. 9539E+00,
$
WITSYS
IWTFLG=             0,
$
SPAFED
XNFEDA=  0. 0000E+00, YNFEDA=  0. 0000E+00, ZNFEDA=  2. 0000E+01, XAFEDA=  0. 0000E+00,
YAFEDA=  0. 0000E+00, ZAFEDA=  2. 0000E+01,
$
PLARY
<
IBSFLG=             1, XBEAMT=  0. 0000E+00, YBEAMT=  3. 4202E-01, NBITS =             4,
LSBRND=             1, IROFF =             0, ITAPER=             1, DENMAX=  1. 0000E+00,
IQ4   =             2,
$
XFORM
<
>
N2    =             9, TXCENT=  0. 0000E+00, TYCENT=  0. 0000E+00, TXSPAN=  1. 0000E+00,
TYSPAN=  1. 0000E+00,
$
TCS
IGRDF =             3, IBAUD =          9600, ICAPLB=             2,
$
CLOSER
```

PLOT # 1 8-AUG-90

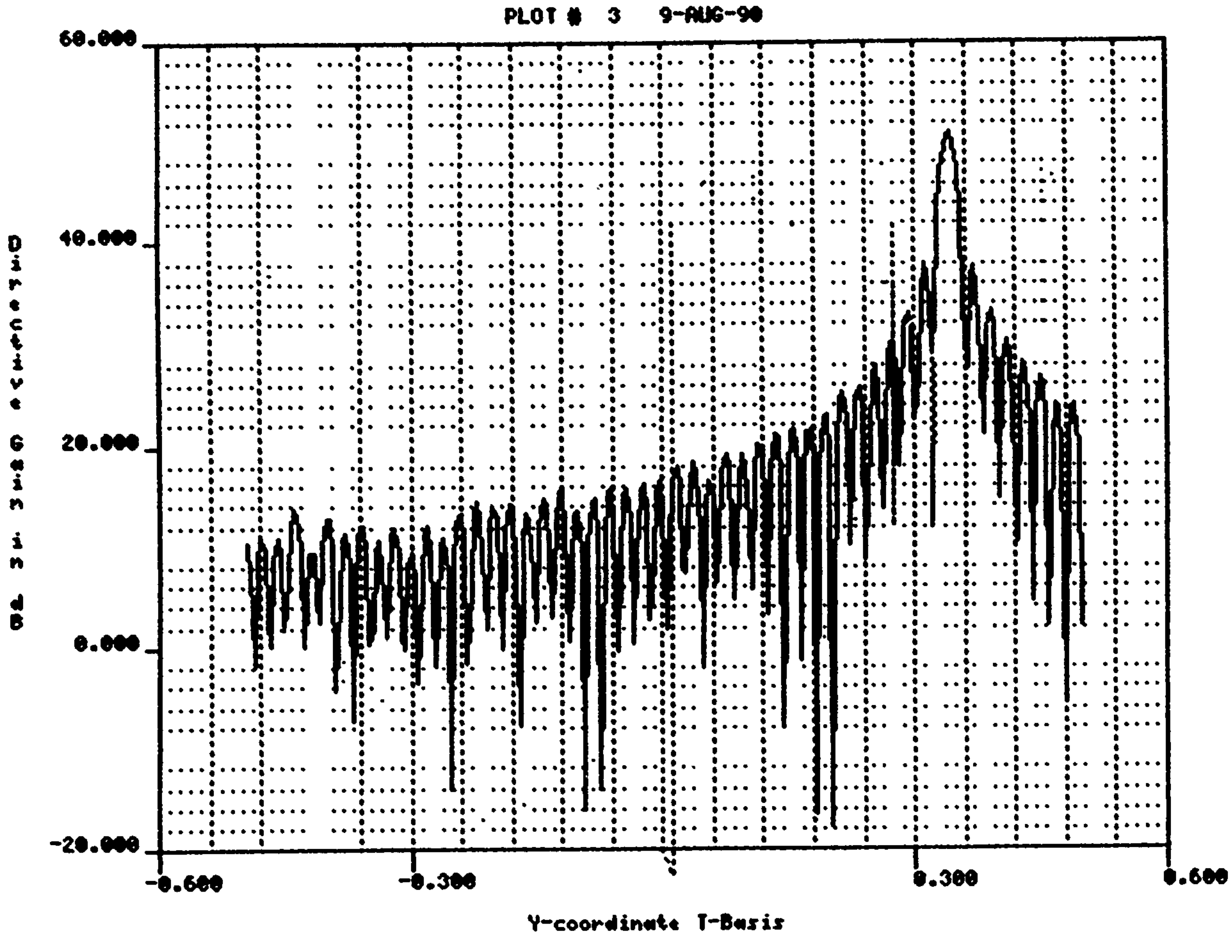
(fig.3)



Surface Diagram of the Array Factor

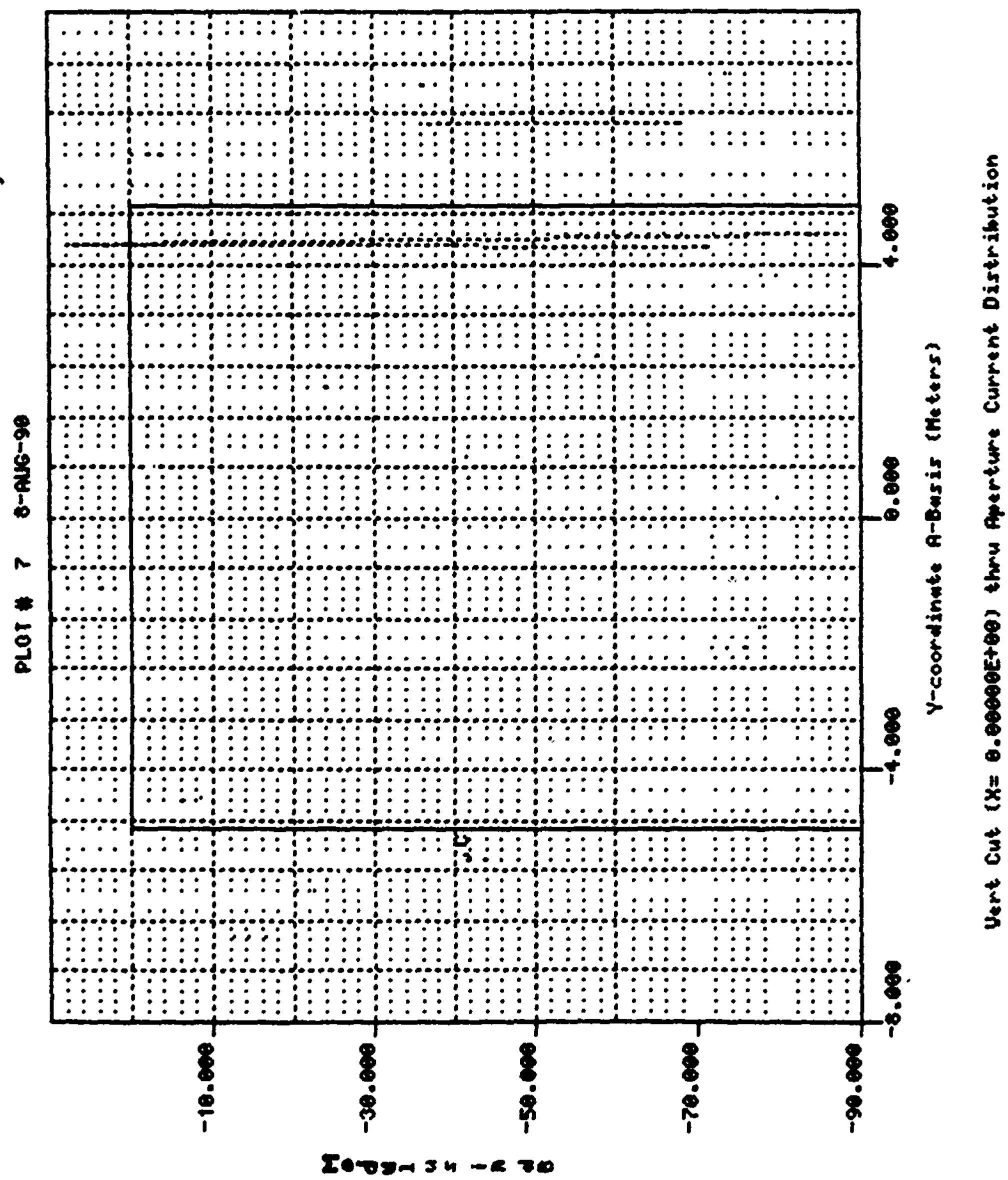
The Peak Directive Gain is 50.956dB

(fig.4)



Vert Cut (X= 0.00000E+00) thru Array Factor
The Peak Directive Gain (Assumes Non-Zero Radiation
only in the Forward Hemisphere) is 0.50955E+02 dB
OCCURS AT X = 0.00000E+00
OCCURS AT Y = 0.34377E+00

(fig. 5)



PLOT # 7 8-AUG-90
-8.000
-4.000
0.000
4.000
-10.000
-30.000
-50.000
-70.000
-90.000
Y-coordinate A-Basis (Meters)
Vert Cut (X= 0.00000E+00) thru Aperture Current Distribution

Test Case # 3

Purpose: The purpose of this simulation was demonstrate the effects of weighting on an antenna radiation pattern. In this case, Cosine weighting was used. All other parameters remained the same.

System Description:

Frequency: 1.5227 GHz

Feed: Ideal Space Feed

Weighting: Cosine

WTPED = .4

NWTPOW = 3

Main Array: Square (L = 9.9078 m)

4 Bit Phase Shifters

Rectangular Element Lattice

Element Spacing = .098504 m

No Beamsteering

Input Data:

Table (3) shows the Run File created for use in PAAS.

Output Data:

A.) PLOT3D was used to show the three-dimensional view of the antenna radiation pattern resulting from the simulation. (fig. 6)

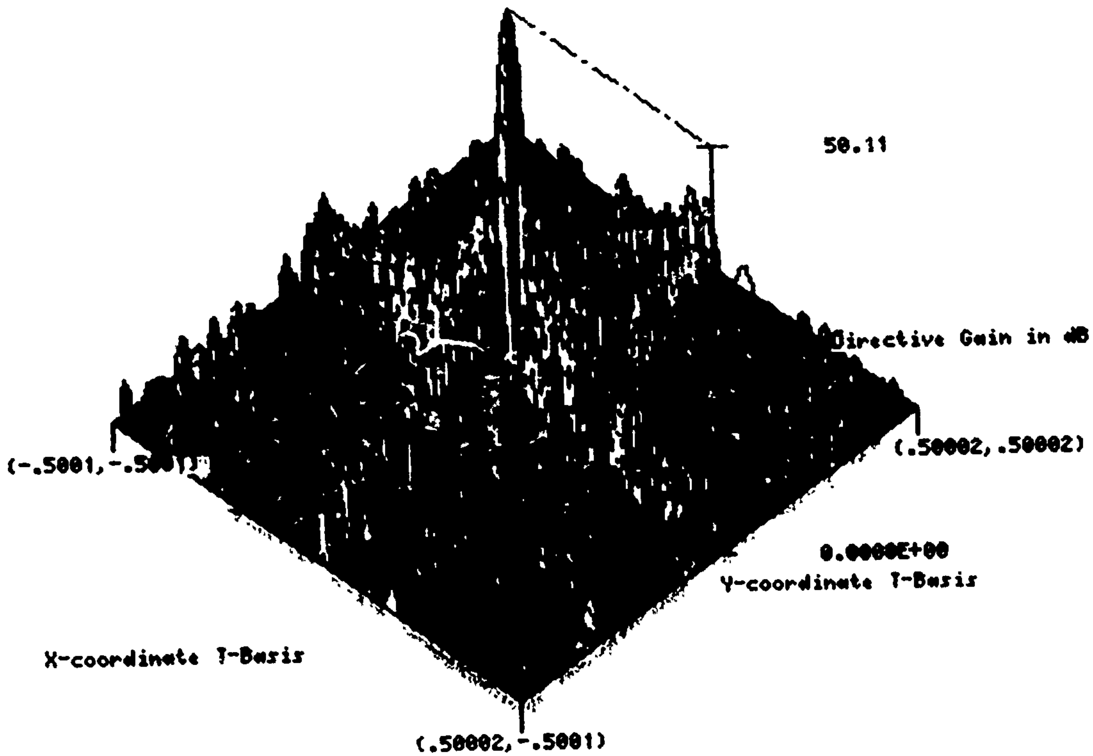
B.) PATCUT was used to show the vertical cut through the mainlobe of the pattern. (fig. 7)

TABLE (3.)

```
SIMSYS
FINST =   1. 5227E+00, FQPER =   1. 5227E+00,
$
LATTICE
ILTYPE=            1, COLSPC=   9. 8504E-02, ROWSPC=   9. 8504E-02,
$
RSHAPE
XWIDTH=   9. 9078E+00, YHIGH =   9. 9078E+00, WTXRAD=   4. 9539E+00, WTYRAD=   4. 9539E+00,
$
WITSYS
IWTFLG=            1,
$
WTPED =   4. 0000E-01, NWTPOW=            3,
$
SPAFED
XNFEDA=   0. 0000E+00, YNFEDA=   0. 0000E+00, ZNFEDA=   2. 0000E+01, XAFEDA=   0. 0000E+00,
YAFEDA=   0. 0000E+00, ZAFEDA=   2. 0000E+01,
$
PLARY
<
IBSFLG=            0, XBEAMT=   0. 0000E+00, YBEAMT=   0. 0000E+00, NBITS =            4,
LSBRND=            1, IROFF =            0, ITAPER=            1, DENMAX=   1. 0000E+00,
IQ4   =            2,
$
XFORM
<
>
N2    =            9, TXCENT=   0. 0000E+00, TYCENT=   0. 0000E+00, TXSPAN=   1. 0000E+00,
TYSPAN=   1. 0000E+00,
$
TCS
IGRDF =            3, IBAUD =         9600, ICAPLB=            2,
$
CLOSER
```

PLOT # 3 8-AUG-90

(fig. 6)

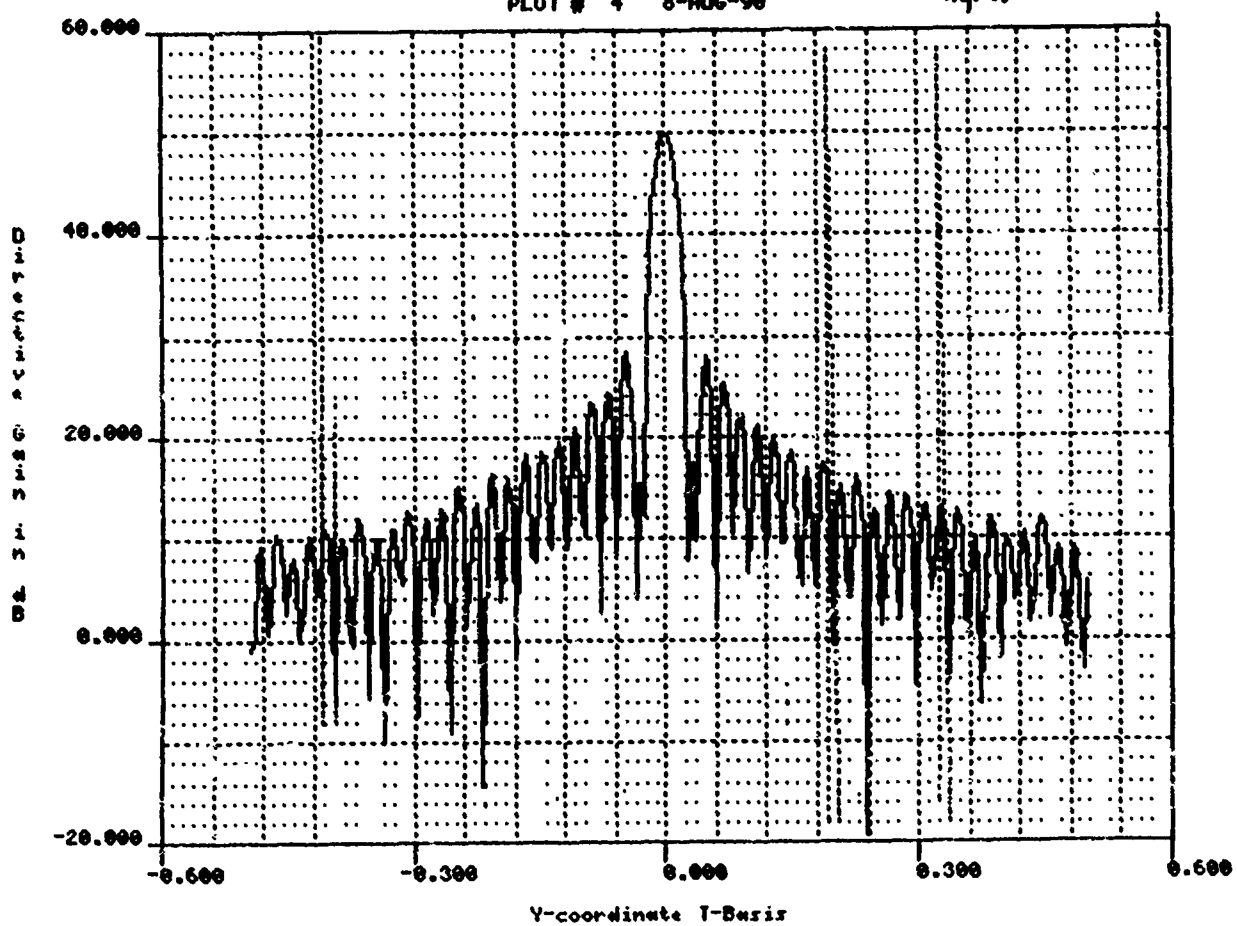


Surface Diagram of the Array Factor

The Peak Directive Gain is 50.113dB

PLOT # 4 8-AUG-90

(fig. 7)



Vert Cut (X= 0.00000E+00) thru Array Factor
The Peak Directive Gain (Assumes Non-Zero Radiation
only in the Forward Hemisphere) is 0.50113E+02 dB
OCCURS AT X = 0.00000E+00
OCCURS AT Y = 0.00000E+00

Test Case # 4

Purpose: The purpose of this simulation was to demonstrate the effects of beamsteering and weighting on the radiation pattern of the nominal case. Cosine weighting was used, and the main beam was steered 20° off boresight in the direction of the positive Y-axis. All other parameters remained the same.

System Description:

Frequency: 1.5227 GHz

Feed: Ideal Space Feed

Weighting: Cosine

WTPED = .4

NWTPOW = 3

Main Array:

Square (L = 9.9078 m)

4 Bit Phase Shifters

Rectangular Element Lattice

Element Spacing = .098504 m

Beamsteering:

XBEAMT = 0.0

YBEAMT = .34202

Input Data:

Table (4) shows the Run File created for use in PAAS.

Output Data:

A.) PLOT3D was used to show the three-dimensional view of the antenna radiation pattern resulting from the simulation. (fig. 8)

(cont.)

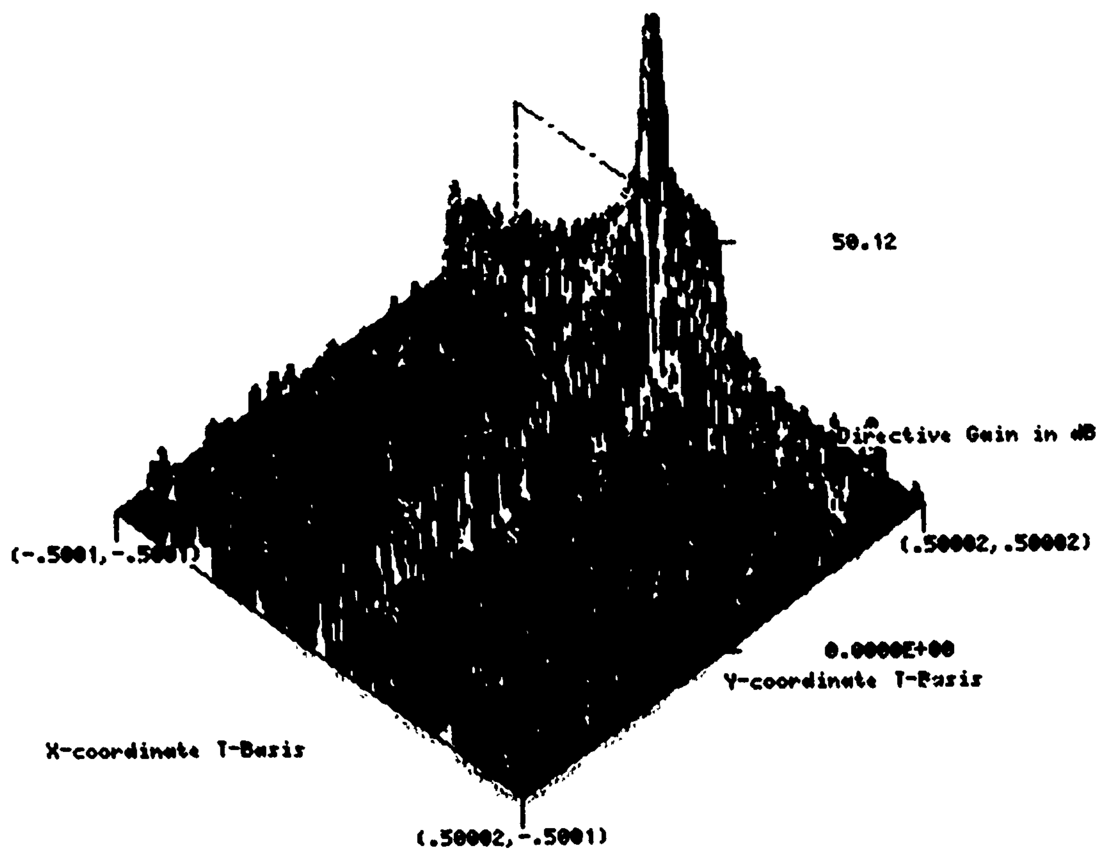
B.) PATCUT was used to show the vertical cut through the mainlobe of the pattern. (fig. 9)

C.) PATCUT was used to show the two-dimensional view of the modulus of cosine weighting in dB. (fig. 10)

TABLE (4.)

```
SIMSYS
FINST =  1. 5227E+00, FOPER =  1. 5227E+00,
$
LATTICE
ILTYPE=            1, COLSPC=  9. 8504E-02, ROWSPC=  9. 8504E-02,
$
RSHAPE
XWIDTH=  9. 9078E+00, YHIGH =  9. 9078E+00, WTXRAD=  4. 9539E+00, WTYRAD=  4. 9539E+00,
$
WITSYS
IWTFLG=            1,
$
WTPED =  4. 0000E-01, NWTPOW=            3,
$
SPAFED:
XNFEDA=  0. 0000E+00, YNFEDA=  0. 0000E+00, ZNFEDA=  2. 0000E+01, XAFEDA=  0. 0000E+00,
YAFEDA=  0. 0000E+00, ZAFEDA=  2. 0000E+01,
$
PLARY
<
IBSFLG=            1, XBEAMT=  0. 0000E+00, YBEAMT=  3. 4000E-01, NBITS =            4,
LSBRND=            1, IROFF =            0, ITAPER=            1, DENMAX=  1. 0000E+00,
IQ4   =            2,
$
XFORM
<
>
N2    =            9, TXCENT=  0. 0000E+00, TYCENT=  0. 0000E+00, TXSPAN=  1. 0000E+00,
TYSPAN=  1. 0000E+00,
$
TCS
IGRDF =            3, IBAUD =         9600, ICAPLB=            2,
$
CLOSER
```

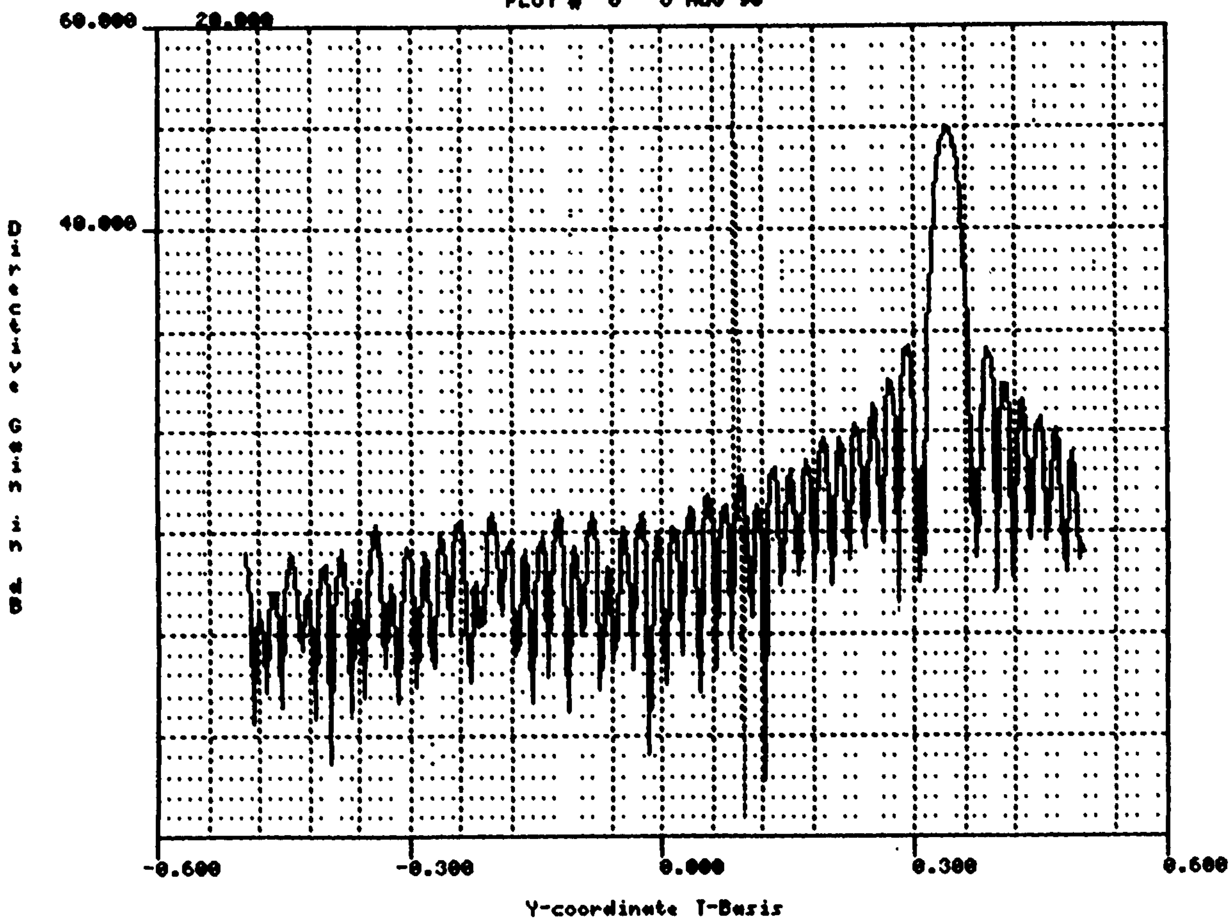
PLOT # 5 8-AUG-90
(fig.8)



Surface Diagram of the Array Factor

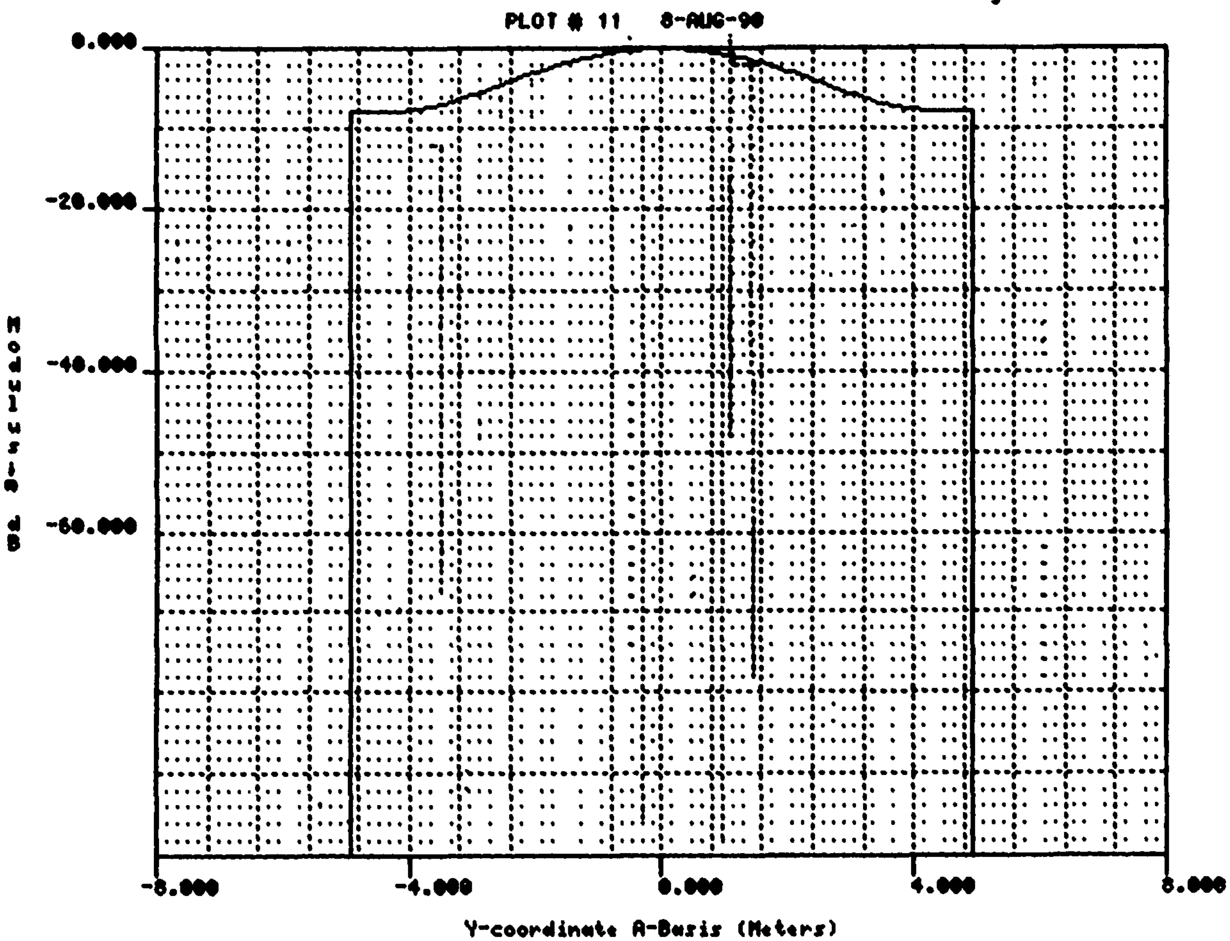
The Peak Directive Gain is 50.117dB

(fig. 9)



Vert Cut (X= 0.00000E+00) thru Array Factor
The Peak Directive Gain (Assumes Non-Zero Radiation
only in the Forward Hemisphere) is 0.50117E+02 dB
OCCURS AT X = 0.00000E+00
OCCURS AT Y = 0.33985E+00

(fig.10)



Vert Cut (X= 0.00000E+00) thru Aperture Current Distribution

CONCLUSION

The effects of weighting on antenna radiation patterns were determined through simulation of a phased array antenna, based on calculations derived from a form of the radar range equation. The parameters of the antenna are as follows:

Frequency: 1.5227 GHz
Feed: Ideal Space Feed
Main Array: Square (Length= 9.9078 m)
4 Bit Phase Shifters
Rectangular Element Lattice
Element Spacing= .098504 m
Loss Totals: 9.9 dB
Peak Transmitting Power: 1 mw
Target Radar Cross-Section: 1 m^2
Range: 250 nmi

An ideal case (Case #1) was simulated using the above parameters and was used as a comparison against the other cases. The antenna gain of the simulation was 51.055 dB. Sidelobe difference was 13 dB. There is no beamsteering in this case.(figs. 1-2) Beamwidth was .86°.

In Case #2 (figs. 3-4), the main beam was steered 20° off boresight. The antenna gain was 50.955 dB and sidelobe difference remained at 13 dB. Beamwidth was measured at 1.07°.

In both of the above cases, uniform weighting was used. The radiation power distribution across the array face is shown in (fig. 5).

In Cases #3 and #4, the weighting factor was changed from

(cont.)
uniform to cosine. The radiation power distribution across the face of the array is shown in (fig. 10). All other parameters remained the same. Case #3 had no beamsteering. The directive gain was 50.113 dB, and the sidelobe difference was 22 dB. The antenna gain in dB of Case #4, where the beam was steered 20° off boresight, was 5.117 dB, and the sidelobe difference remained at 13 dB. The beamwidths of Cases #3 and #4 were 1.29° and 1.5°, respectively.

This implies that the addition of cosine weighting to the phased array antenna being simulated slightly reduces the directive gain (about 1 dB), reduces the sidelobes by a large amount (about 9 dB), and increases the beamwidth by a relatively small amount (.64°). Therefore, by changing the weighting from uniform to cosine, the radiation pattern was altered, resulting in significantly reduced sidelobes with small sacrifices in directive gain and beamwidth.

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Todd Gleason

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1990 High School Apprenticeship Program
Cartographic Applications
Rome Air Development Center
Mentor: Stephen Hnat
Apprentice: Christopher S. Hailes
June 24- August 22 1990

Acknowledgements

First and foremost, I would like to thank Capt. Roderick Holland for all his time and help. He always had to escort me into and out of the Intelligence Cartographic Facility (ICF) area, for which everyone needs a special clearance. He helped me carry loads of charts, maps and data on other mediums to my desk. There were days in which he escorted me eight times. I always felt uncomfortable doing this, continually interrupting his work day, but he never appeared to be bothered by this. On the contrary, he always appeared to be happy to help me or answer my many questions, and for this I am grateful. He helped make my adjustment into the office easy.

I would also like to thank Stephen Hnat for making the morning hours so enjoyable. We would often talk about work or engineering; I learned a great deal from our talks. I have a clearer picture of what to expect from jobs and the type of education I will need to receive.

Captain Barnhill also helped me feel more comfortable in adjusting to the office life. He always made it a point to invite me to the office get-togethers, especially at lunch. Probably the highlight of this summer experience came when I saw my work being utilized. Both Capt. Barnhill and Lt. Tidball asked to see my inventory to determine if RADC had the maps they needed and then asked me to find certain maps for them. It was a nice feeling knowing that my work was already being put to use.

I would also like to thank Mary Ann Urbanik for escorting me into the ICF when I couldn't find Capt. Holland. Finally I would

like to thank Delores Spado, James Mcneely, Capt. Marquez. Paul Hagerty, and Maj. Burgess for a good time at RADC and showing me what to expect from jobs in the future.

General Description of Job Experience

During my eight week summer internship at Rome Air Development Center (RADC) I was responsible for populating the Macintosh data base with all the charts at RADC. In other words, I inventoried all the hardcopy maps and maps in digital form. In the process of doing this, I also reorganized the maps and the digital products. This I did by putting the maps and map storing devices in alphabetical and numerical order.

RADC is continuously loaning out its charts to contractors. Prior to my inventory there was not an easy system by which to keep track of the products. Storing the charts on the computer greatly simplified the retrieval process. With the current system, each map or digital product listing has a space for additional information, i.e. to whom the maps are loaned, their general location and other necessary information. This new system makes it easier for the people at RADC to find out if the maps needed by contractors are available, without going into the (ICF) and searching through all the charts. There are literally thousands of such maps and digital products. Now, all one has to do is use the computer s search function to find individual maps and digital products. This takes all of two to three minutes. Consequently, it is much easier to keep track of all the products and locate them.

Detailed Description

RADC has thousands of maps. Some are on paper and others

are stored on various digital mediums such as compact discs, 9-track tapes, floppy discs, and video discs. It was my job to take down all the important information from the product and record it on the computer. With this information anyone can search through the data base to determine if RADC owns a certain product and also find out relevant information about the individual product. The information I recorded invariably included the stock number, publishing date, edition number, geographic area coverage and number of copies of the individual product.

My first step in this project was to inventory all the products on paper, and at a later date I would input the information onto the computer. At the beginning of the summer a contractor was using the computer, and it was located in the ICF, a secured area. That meant that I had to be accompanied at all times while in this area. Considering that my mentor, Capt. Holland had work of his own to do, this was not a viable option. Consequently, I inventoried the products on paper until the contractor finished his work. Approximately three weeks into the summer the computer was moved out of the ICF so that I could use it and start inputting the information.

Each entry looked somewhat like this:

Stock #	Edit #	# of copies	Edit Date	Geo Coverage
TFCXXH06A	2	4	4/86	34-35N/86-88E

After the Macintosh was brought out of the secured area, I alternated between inventorying maps from the ICF to entering

this data into the computer. The program I was using had already been set up to receive the information. When entering the information into the computer, it was merely a question of filling blanks in the program. After inputting a decent amount of information, I would print that information and then double check the printout with my original, handwritten copy for any mistakes.

In the end I managed to complete most of the inventorying. I did not finish inventorying about a half of a cabinet of charts. I also did not finish inputting into the computer about five pages of information I had already inventoried. It would take approximately two more weeks to complete inventorying and inputting that information.

Observations

I can truthfully say that I learned a lot through this mentorship program and I am glad that I had the opportunity to work at RADC. I learned what to expect in the work environment and picked up interesting and useful information from conversations and listening to people talk about their jobs. But, if a purpose of this program was to "give a first-hand understanding of scientific methods," that was not fully achieved. I was not involved in or exposed to any "scientific work." Because of the nature of the work at RADC, they were limited in the work they could give me. Furthermore, I lacked the educational background necessary for actively being involved in their scientific and engineering work, which again limited the type of work I could be assigned.

Reqardless, this summer internship was a valuable lesson and I enjoyed the experience. I would especially like to thank all those responsible for this opportunity.

Application Software Development for use on Directory Specific Network

Edward Holmes

Norman J. Sturdevant

Rome Air Development Center

August 14, 1990

Acknowledgements

My summer apprenticeship was very successful and fulfilling. There are a few people to whom I am very greatful for what they have done for me.

I would like to thank Norman J. Sturdevant taking the time to work with me and give me the opportunity to work in such a fine facility. He has helped me get off to a good start in seeking a career. I have seen how interesting and exiting the computer and engineering fields can be. Mr. Sturdevant has taught me many new things. I am very greatful for what he has done for me.

I would also like to thank Christopher Stauring for contributing to the success of the project. Chris is working with the Junior Fellowship program. We worked on this project together. We accomplished more than we expected to. Chris helped me many times when I needed help and for that I am very greatful.

I would also like to thank some other workers in the office. Dino Pacini, Bob Falbo, Jim McNichol, and Paul Kasper have made my apprenticeship rewarding and enjoyable. They have helped me understand more about the work they do. They have made me feel right at home. I am thankful that I have had the opportunity to work with them.

My summer apprenticeship was spent at Rome Air Development Center where I worked on a project called "Application Software Development for use on Directory Specific Network." This project was researched and later put to use in the designing of the new software program. The finished product was successful and close to being perfect.

"Application Software Development for use on Directory Specific Network" is a project in which my partner and I rewrote a program written in D-Base in Paradox 3. The program that we worked on is called "RADC Form 38." The original program was created to store records of employees. Information that was stored included hours, job order numbers, civilian/military status, work type, and branch office. The program allowed the user to edit, add, or delete hours, employees, and job order numbers. We rewrote the program in Paradox 3 for many reasons. Paradox 3 is a relational database and is network compatible. We also used Paradox 3 because we could make the program menu driven and user friendly. The results of this project are the fact that the new rewritten program is more user friendly and efficient than the old program. Those were the goals that we set for ourselves at the start of our work.

To begin the project, we had to learn how to use Paradox 3. The most important part of learning Paradox 3 was PAL. PAL is the Paradox Application Language. PAL contains the commands that were necessary for writing the scripts that ran the program. There were four major sections to the

program. The two that I worked on were the "Hours" and "Employees" scripts.

The Hours script allows the user to select a job order number from a table. When the job order number is selected, a table containing employees and their hours for the selected job order number will appear. The user may edit the hours in the table. There were some difficulties writing the script. Eventually, these problems were solved. The list of job order numbers had to be in numerical order. This problem was solved by running the table through a query. A query will separate a selected column from a table and put the contents of the column in alphabetical or numerical order. Another problem was transferring the edited changes to the data table. This problem was overcome by using a smaller script that would transfer the changes to data table. This script runs a loop that searches the editing table, assigns variables to the values, and transfers the new values to the data table by overwriting the old values. One other problem that was important to the development of the program was assigning a variable to a value listed in a table. If a cursor selected a value from a table, an equation needed to be present. That equation was "Variable = [Column Name]." The researching, writing, and developing of the Hours script was complicated but gradually became a task that became easier as more time was spent on it.

The Employee script allows the user to edit an employees record. It also allows the user to add or delete an employee.

When the user chooses to edit an employees record, a list of all employees will be available for the user to choose from. When an employee is chosen, the user has the choice to update the record or to delete it. When Update is chosen, the user may change the employees name, civilian/military status, work type, branch office, or hours for an job order number. The user will use an edit screen to make these changes. If the user decides to save the changes, a script will run a search of the data table and replace the old values with the ones entered by the user. Again, the new values will have variables assigned to them. When the user chooses to delete an employee, a menu will appear asking the user to select Yes or No. If the user chooses to delete the employee, a variable will be assigned to the name, and all information associated with that name will be erased. When the user chooses to add an employee, the same edit screen will appear as when Update is chosen. The user may enter the name and information of a new employee. One major problem was finding the total number of hours that an employee had for all job order numbers. This problem was solved by allowing the user to press a key designated to display the total hours. An employee may not work more than 1,728 hours in a fiscal year. We also added a warning when the user entered hours that totaled more than 1,728. The Employee script was more difficult and complex than the Hours script. But, it still became easier as more time was spent working on it.

The results of this project were very extraordinary. We

did not expect to finish the entire program. By the end of the summer, the program was in working condition. Although it was not perfect, it still performed as well as the old program. During the research and development of the program we discovered many new things about Paradox 3. We learned in a short period of time how to assign variables to numbers or words, run loops, and assign functions to keystrokes. We also discovered that Paradox 3 takes up a lot of memory space and may cause an error when the memory is full. That was important because we were able to recognize the problem and begin research to correct it. We can conclude that the project was a success and that with more time could have been perfected.

My experience this summer with the high school apprenticeship program was very valuable. It is unbelievable how much I have learned in just eight weeks. I have learned the importance of responsibility, working with other people, and the use of available resources. The apprenticeship has also given me valuable experience. I have experienced working in a professional business atmosphere unlike anything I have experienced before. I have been able to look toward the future because of the apprenticeship. I would like to continue studying computer science and engineering. I also discovered that I would like to work in a position similar to the one that I had this summer. This apprenticeship has been the greatest educational and career experience that I have ever had.

```
;HOURS.SC

CLEARALL CLEAR          ; clears everything on the screen
                        ; this script is executed when "Hours" is
                        ;      selected from the main menu(Form38)
SHOWMENU                ; displays the new menu
  "Select JON" : "View List Of JONs, Select JON To Edit",
  "Quit" : "Return To Main Menu"
; "Select JON" & "Quit" are menu choices followed by their description
TO CHOICE               ; enables choice to be made
SWITCH                  ; allows choice to be executed
  CASE (CHOICE = "Select JON"):   ; when "Select JON" is chosen the commands
                                  ;      below will be executed
  PLAY "Jonlist"                  ; updates the "Hours2" table
  MENU {View} {Hours2}       ; script will go to main menu, choose the view
                             ;      command and view "Hours2" table
  PROMPT "Use arrows, PGUP, PGDN, HOME, and END to move cursor",
        "Press ENTER to select JON, press F10 to return to menu"
; help statements to be displayed at the top of the screen
  WHILE(TRUE)                ; allows user to move around the field
  MOVETO[JON]                ; cursor will move to JON field
  WAIT FIELD                 ; allows user to move around the field
                             ;      until certain keys are hit
  UNTIL "ENTER","F10","DOWN","UP","PGDN","PGUP","LEFT","HOME","END"
; user may move around field until user presses one of the keys indicated
      SWITCH                      ; allows keystroke to be executed
         CASE RETVAL = "DOWN":    ; "DOWN" is chosen
           DOWN                   ; moves cursor down
         CASE RETVAL = "UP":      ; "UP" is chosen
           UP                     ; moves cursor up
         CASE RETVAL = "PGDN":    ; "PGDN" is chosen
           PGDN                   ; allows pagedown keystroke to be exeruted
         CASE RETVAL = "PGUP":    ; "PGUP" is chosen
           PGUP                   ; allows pageup keystroke to be executed
         CASE RETVAL = "HOME":    ; "HOME" is chosen
           HOME                   ; moves cursor to the top of the column
         CASE RETVAL = "END":     ; "END" is chosen
           END                    ; moves cursor to the bottom of the column
         CASE RETVAL = "ENTER":   ; "ENTER" is chosen
           MENU DELETE "Answer1"
           MENU DELETE "Answer2"
; "Answer1" and "Answer2" must be deleted to allow new answer tables to be used
; allow the table names to be reused
           REC=[JON]              ; assigns variable REC to selected JON
           CLEARALL               ; clears everything on the screen
           PLAY "RECORD"          ; plays the "RECORD" query
                                  ; displays employees and their hours
           DO_IT!                 ; executes the query
           MENU RENAME "Answer" "Answer2"
; the "Answer" query is renamed "Answer2"
           PLAY "RECORD2"         ; plays the "RECORD2" query
                                  ; displays total hours for all employees
                                  ;      for JON selected
           DO_IT!                 ; executes the query
           MENU RENAME "Answer" "Answer1"
; the "Answer" query is renamed "Answer1"
           CLEARALL CLEAR         ; clears everything on the screen
           MENU {View} {Answer2}  ; script goes to the menu, chooses the "View"
                                  ;      command, and views the "Answer2" table
           MENU {View} {Answer1}  ; script goes to the menu, chooses the "View"
                                  ;      command, and views the "Answer1" table
           UPIMAGE                ; moves to the "Answer2" table
           EDITKEY                ; begins edit mode
           MOVETO[Hours]          ; cursor will be in hours field
           PROMPT "Press F10 to save changes, press ESC to cancel",
           REC
; help statements to be displayed at the top of the screen, JON is displayed
           WHILE (TRUE)           ; allows user to move around the table
           WAIT FIELD             ; allows user to edit until certain keys
                                  ;      are hit
           UNTIL "F10","ESC","UP","DOWN","PGUP","PGDN","HOME","END","ENTER"
```

```
          SWITCH                ; allows choice to be made
            CASE RETVAL = "F10":
              MENU DO_IT! PLAY "Edithour" CLEARALL {View} {Hours2}
; when f10 is pressed the script will go to the menu, execute the edit, play
;      the "Edithour" script which will transfer the edited changes to the
;      "Hours" table, the screen will then be cleared, the view command will
;      be executed, and the "Hours2" table will be viewed
              PROMPT "Use arrows, PGUP, PGDN, HOME, and END to move cursor",
              "Press ENTER to select JON, press F10 to return to menu"
; help statements to be displayed at the top of the screen
            QUITLOOP                          ; loop ends
            CASE RETVAL = "ESC":
              MENU CANCELEDIT CLEARALL {View} {Hours2}
; when ESC is selected the script will cancel the editing changes, clear
;      everything on the screen, choose the view command and view the {Hours2}
;      table
              PROMPT "Use arrows, PGUP, PGDN, HOME, and END to move cursor",
              "Press ENTER to select JON, press F10 to return to menu"
; help statements to be displayed at the top of the screen
            QUITLOOP                          ; loop ends
            CASE RETVAL = "UP":               ; "UP" is chosen
              UP                              ; cursor moves up
            CASE RETVAL = "DOWN" OR RETVAL = "ENTER":    ; "DOWN" OR "ENTER"
                                                         ;      is chosen
              SWITCH                          ; switch choice
                 CASE ATLAST()=TRUE :         ; if the cursor is in the last
                    END                       ;       row, it will stay there
                 CASE ATLAST()<>TRUE:         ; if the cursor is not in the
                    DOWN MOVETO[Hours] EDITKEY  ;last row, it will go down
              ENDSWITCH                       ; switch choices end
            CASE RETVAL = "PGUP":             ; "PGUP" is chosen
              PGUP                            ; pageup is executed
            CASE RETVAL = "PGDN":             ; "PGDN" is chosen
              PGDN                            ; pagedown is executed
            CASE RETVAL = "HOME":             ; "HOME" is chosen
              HOME                            ; cursor moves to top
            CASE RETVAL = "END":              ; "END" is chosen
              END                             ; cursor moves to bottom
          ENDSWITCH                           ; switch choices end
        ENDWHILE                              ; while ends
      CASE RETVAL = "F10":                    ; "F10" is chosen
      QUITLOOP                                ; ends loop
    ENDSWITCH                                 ; switch choices end
  ENDWHILE                                    ; while ends
  DO_IT!                                      ; return to previous screen
  CLEARALL PLAY "HOURS"            ; clears everything on the screen, plays
                                   ;       "HOURS" script
CASE (CHOICE = "Quit"):            ; "Quit" is chosen
  CLEARALL PLAY "FORM38"           ; clears everything on the screen, plays
                                   ;       "FORM38" script
ENDSWITCH                          ; switch choices end
```

```
;EDITHOUR.SC

MENU {View} {Answer2}       ; view the "Answer2" table
MENU {View} {Hours}         ; view the "Hours" table
MOVETO[JON]                 ; moves to JON field in "Hours" table
LOCATE REC                  ; locates REC, the JON selected by the user
WHILE retval                ; searches for the first REC
SLEEP 1000                  ; pauses for one second when it is found
MOVETO[NAME]                ; moves to NAME field in "Hours" table
X = [NAME]                  ; X is assigned to the name
MOVETO[Answer2 ->]          ; moves to "Answer2" table
MOVETO[NAME]                ; moves to NAME field
LOCATE X                    ; locates X
MOVETO[HOURS]               ; moves to HOURS field
Y = [HOURS]                 ; Y is assigned to the number
MOVETO[Hours ->]            ; moves to "Hours" table
MOVETO[JON]                 ; moves to JON field
LOCATE REC,X                ; locates the REC for X
MOVETO[HOURS]               ; moves to HOURS field
EDITKEY                     ; goes into edit mode
BACKSPACE BACKSPACE BACKSPACE BACKSPACE       ; backspaces to erase old hours
TYPEIN Y                    ; replaces with Y
ENTER                       ; enters the number
MOVETO[JON]                 ; moves to JON field
DOWN                        ; goes down
LOCATE NEXT REC             ; locates next REC
ENDWHILE                    ; search ends when last REC is found
DO_IT!                      ; saves changes, ends script
; the purpose of this script is to transfer the changes made in the "Answer2"
;      table to the "Hours" table. the next time the tables are used, all the
;      changes will be updated in the "Hours" table
```

```
;RECORD.SC

Query

 Hours | JON    | Name  | Hours |
       | =~REC  | Check | Check |
       |        |       |       |
       |        |       |       |

Endquery

; this query will look for all JONs equal to REC. REC is assigned to the JON
;       selected by the user.  the result will be a table that will hold the
;       names and hours for the JON that was selected.
```

```
;RECORD2.SC

Query

 Answer2 |  Hours   |
         | calc sum |
         |          |
         |          |

Endquery

; this query will find the total number of hours by the employees. the result
;      will be a table that will display the total.
```

```
;JONLIST.SC

Query

 Jonstabl | Jon     |
          | Check   |
          |         |
          |         |

Endquery

; this query will list all the present JONs

DO_IT!
DELETE "Hours2"
RENAME "Answer" "Hours2" CLEARALL
; this will update the old table by making a new answer table with the updated
;      information, deleting the old table and renaming the answer table
;      "Hours2"
```

;EMPLOYEE.SC

```
CLEARALL CLEAR                          ; clears everything on the screen
; this script is executed when "Employee" is selected from the main menu(Form38)
SHOWMENU                                ; displays new menu
  "Edit" : "Edit Or Delete Employees Hours",
  "Add" : "Add An Employee And Enter Hours",
  "Quit" : "Return To Main Menu"
; "Edit", "Add", & "Quit" are menu choices followed by their descriptions
TO CHOICE                               ; enables choice to be made
SWITCH                                  ; allows choice to be executed
     CASE (CHOICE = "Edit"):            ; "Edit" is chosen
         RESET PLAY "Edit"              ; plays the "Edit" script
         ; "Edit" goes to the list of employees
     CASE (CHOICE = "Add"):             ; "Add" is chosen
         RESET PLAY "Add"               ; plays the "Add" script
         ; "Add" goes to the add screen
     CASE (CHOICE = "Quit"):            ; "Quit" is chosen
         CLEARALL PLAY "FORM38"         ; clears the screen, plays "FORM38"
         ; "Form38" will go to the main menu
ENDSWITCH                               ; switch choices end
```

;EDIT.SC

```
PLAY "Sortpepl" CLEARALL            ; plays the "Sortpepl" script
; "Sortpepl" sorts the "People" table into alphabetical order
MENU {View} {People}                ; go to menu and view "People" table
; "People" table contains list of employees
PROMPT"Use arrows, PGUP, PGDN, HOME, and END to move cursor",
      "Press ENTER to select employee, press F10 to quit"
; help statements to be displayed at the top of the screen
WHILE (TRUE)                        ; allows user to move freely around field
   MOVETO [Name]                    ; moves to "Name" field
   WAIT FIELD                       ; allows user to move freely around field
   UNTIL "ENTER","F10","UP","DOWN","PGUP","PGDN","HOME","END"
   ; selected keys are functional
   SWITCH                           ; allows keystrokes to be executed
      CASE RETVAL = "UP":           ; "UP" is chosen
         UP                         ; cursor moves up
      CASE RETVAL = "DOWN":         ; "DOWN" is chosen
         DOWN                       ; cursor goes down
      CASE RETVAL = "PGUP":         ; "PGUP" is chosen
         PGUP                       ; "PGUP" will be executed
      CASE RETVAL = "PGDN":         ; "PGDN" is chosen
         PGDN                       ; "PGDN" will be executed
      CASE RETVAL = "HOME":         ; "HOME" is chosen
         HOME                       ; cursor will move to the top of the column
      CASE RETVAL = "END":          ; "END" is chosen
         END                     ; cursor will move to the bottom of the column
      CASE RETVAL = "F10":       ; "F10" is chosen
         CLEARALL PLAY "Employee" QUITLOOP
         ; "Employee" will go back to employee menu
         ; screen is cleared, "Employee" script is played, loop ends
      CASE RETVAL = "ENTER":     ; "ENTER" is chosen
         REF = [Name]            ; "REF" is assigned to the name chosen
         CLEARALL                ; screen is cleared
         PLAY "Erasecol"         ; "Erasecol" script is played
         , "Erasecol" will erase the "Hours" field of the "Jonhour" table
         PLAY "Menu2"            ; "Menu2" script is played
         ; "Menu2" will go to the edit menu
         QUITLOOP                ; loop ends
   ENDSWITCH                     ; switch choices end
ENDWHILE                         ; while ends
```

```
;ADD.SC


CLEARALL CLEAR              ; screen is cleared
VAR=0
@ 0,0                       ; positions cursor at top left corner
??"Enter New Employee Name:" ; command to the user
ACCEPT "A4" TO P            ; user enters respose(P)
CLEARALL                    ; clears the screen
View "People" MOVETO [Name]
; goes to menu, views "People" moves to "Name" field
; "People" table contains list of employees
LOCATE P                    ; locates name(P)
NA = [Name]                 ; assigns "NA" to name
IF P = NA                   ; if names are the same
     THEN CLEARALL          ; then clear the screen
     @0,0 ?"YOU HAVE ENTERED A NAME THAT ALREADY EXISTS"
     ; message tells user that name entered has already been used
     SLEEP 5000             ; pauses for five seconds
     RESET PLAY "Add"       ; plays employee script
                            ; starts the script over again
ENDIF                       ; ends if statement
T = ""                      ; no name is entered
IF P = T                    ; if no name is entered
     THEN CLEARALL          ; the screen will be cleared
     @0,0 ?"YOU MUST ENTER A NAME"    ; the message will be displayed
     SLEEP 5000                       ; pause for five seconds
     RESET PLAY "Add"                 ; play the "Add" script
                                      ; starts the script over again
ENDIF                                 ; if statement ends
@ 5,0                       ; positions cursor 5 lines from the top
??"Enter (C)ivilian Or (M)ilitary:"   ; command to the user
ACCEPT "A1" TO A_Q          ; user enters response(Q)
@ 10,0                      ; positions cursor 10 lines from the top
??"Enter S & T Code:"       ; command to the user
ACCEPT "A1" TO R            ; user enters response(R)
@ 15,0                      ; positions cursor 15 lines from the top
??"Enter Branch Office:"    ; command to the user
ACCEPT "A4" TO S            ; user enters response(S)
CLEARALL                    ; clears the screen
PLAY "Erasecol"             ; plays "Erasecol"
; "Erasecol" clears the "Hours" field in the "Jonhour" table
View "Jonhour"              ; goes to menu, views "Jonhour"
; "Jonhour" contains JONs and hours for selected employee
PROMPT "Press F10 to save, press ESC to cancel, and press F1 to view total sum of hours",
P                           ; displays message and employee
MOVETO [Hours]              ; moves to "Hours" field
EDITKEY                     ; goes into edit
WHILE (TRUE)                ; allows user to move around field
     WAIT FIELD             ; waits until certain keys are pressed
     UNTIL "F10", "ESC", "ENTER", "UP", "DOWN", "PGUP", "PGDN", "HOME",
          "END","F1"        ; selected keys are functional
     SWITCH                 ; allows choice to be made
         CASE RETVAL = "UP":      ; "UP" is chosen
              UP                  ; cursor moves up
         CASE RETVAL = "DOWN" OR RETVAL="ENTER"   :    ; "DOWN" or "ENTER"
                                                       ;      is chosen
            SWITCH          ; allows choice to be made
                CASE ATLAST()=TRUE :      ; if cursor is in the last row
                     END                  ; it will remain there
                CASE ATLAST()<>TRUE :     ; if cursor is not in the last row
                    DOWN MOVETO[Hours] EDITKEY   ; it will move down
            ENDSWITCH                     ; switch choices end
         CASE RETVAL="F1":                ;Case to view the sum of hours if F1.
           LEFT REC=[]                    ;Move to the left and store the JON in REC.
           DO_IT!                         ;Save the Jonhour table.
           PLAY "HRSUM"                   ;Play the HRSUM query.
             IF SUM>1728 THEN               ;Test if Sum is greater than 1728.  If it is then
             BEEP BEEP                    ;beep twice, show the hours, and a warning.
             @20,45 ?? "YOUR TOTAL HOURS ARE ",SUM
             @21,45 ?? "YOU ARE OVER 1728 HOURS BY ",SUM-1728
             @22,45 ?? "PLEASE ADJUST TO 1728" SLEEP 8000
```

```
   ELSE                              ;If sum is less than 1728, then just
   MESSAGE "TOTAL HOURS = ",SUM SLEEP 2000 ;show the total hours.
  ENDIF
  CLEARALL CLEAR
  VIEW "JONHOUR"                     ;View the Jonhour table again.
  RIGHT LOCATE REC                   ;Locate the JON stored in Rec.
  MOVETO [HOURS]                     ;Move to the hours field.
  EDITKEY                            ;Begin editing.
CASE RETVAL = "PGUP":    ; "PGUP" is chosen
   PGUP                  ; "PGUP" is executed
CASE RETVAL = "PGDN":    ; "PGDN" is chosen
   PGDN MOVETO [Hours] EDITKEY   ; "PGDN" is executed

CASE RETVAL = "HOME":    ; "HOME" is chosen
   HOME                          ; cursor moves to the top of the screen
CASE RETVAL = "END":     ; "END" is chosen
   END MOVETO [Hours] EDITKEY    ; cursor moves to the bottom
                                 ;      of the screen
CASE RETVAL = "ESC":     ; "ESC" is chosen
   CANCELEDIT RESET PLAY "Employee" QUITLOOP
   ; "Employee" will go to the employee menu
   ; cancels edit, clears the screen, plays the "Employee"
   ;       script, quits the loop
CASE RETVAL = "F10":     ; "F10" is chosen
   MENU DO_IT!           ; goes to menu, saves the changes
   MENU {View} {Name}    ; goes to menu, views "Name" table
   ; "Name" table contains employee name, C/M, type, and office
   END                   ; goes to the end of the table
   EDITKEY               ; goes into edit
   DOWN                  ; moves down
   MOVETO [Name]         ; moves to the "Name" field
   TYPEIN P              ; types "P"
   MOVETO [C/M]          ; moves to the "C/M" field
   TYPEIN A_Q            ; types "Q"
   MOVETO [Type]         ; moves to the "Type" field
   TYPEIN R              ; types "R"
   MOVETO [Branch]       ; moves to the "Branch" field
   TYPEIN S              ; types "S"
   DO_IT!                ; saves the changes
   CLEARALL              ; clears the screen
   MENU {View} {People} ; goes to the menu, views "People"
   ; "People" contains list of employees
   END                   ; moves to the end of the table
   EDITKEY               ; goes into edit
   DOWN                  ; moves down
   MOVETO [Name]         ; moves to the "Name" field
   TYPEIN P              ; types "P"
   DO_IT!                ; saves the changes
   CLEARALL              ; clears the screen
   MENU {View} {Jonhour}; goes to the menu, views "Jonhour"
   ; "Jonhour" contains JONs and hours for selected employee
   PLAY "Addnew"         ; plays the "Addnew" script
   ; "Addnew" will create a table with the new employees
   ;      hours, so they can be transfered to the "Hours"
   ;      table.
   DO_IT!                ; saves the changes
   CLEARALL              ; clears the screen
   MENU {View} {Hours}   ; goes to the menu, views "Hours"
   MENU {View} {Answer} ; goes to the menu, views "Answer"
   ; "Hours" table contains JONs, hours, and employees
   ; "Answer" table contains JONs and hours for a new employee
   MOVETO [JON]          ; moves to the "JON" field
   D = "Answer"          ; checks to see if table is empty
   IF ISEMPTY(D) = TRUE
      THEN DO_IT! RESET PLAY "Employee" QUITLOOP
      ; saves the changes, clears the screen, plays the
      ;       "Employee" script, quits the loop
      ; "Employee" script will go to the main menu
   ENDIF                 ; table check ends
   WHILE (TRUE)          ; begins while loop
   SLEEP 1000            ; pauses for a second
   J = [JON]             ; assigns "J" to the JON
```

```
            MOVETO [Hours]           ; moves to "Hours" field
            K = [Hours]              ; assigns "K" to the hours
            EDITKEY                  ; goes into edit
            DEL                      ; deletes the line
            DO_IT!                   ; saves the changes
            MOVETO [HOURS ->]        ; moves to the "Hours" table
            END                      ; moves to the end of the table
            EDITKEY                  ; goes into edit
            DOWN                     ; moves down
            MOVETO [JON]             ; moves to the "JON" field
            TYPEIN J                 ; types "J"
            MOVETO [Name]            ; moves to the "Name" field
            TYPEIN P                 ; types "P"
            MOVETO [Hours]           ; moves to the "Hours" field
            TYPEIN K                 ; types "K"
            DO_IT!                   ; saves the changes
            MOVETO [Answer ->]       ; moves to the "Answer" table
            MOVETO [JON]             ; moves to the "JON" field
            W = "Answer"             ; checks to see if table is empty
            IF ISEMPTY(W) = TRUE
                THEN DO_IT! RESET PLAY "Employee" QUITLOOP
                ; saves the changes, clears the screen, plays the
                ;       "Employee" script, ends the loop
                ; "Employee" script will go to the main menu
            ENDIF                    ; table check ends
            DOWN                     ; moves down
            ENDWHILE                 ; while loop ends
            QUITLOOP                 ; loop ends
    ENDSWITCH                        ; switch choices end
ENDWHILE                             ; while statement ends
```

;MENU2.SC

```
CLEARALL CLEAR                          ; clears the screen
SHOWMENU                                ; displays menu
"Update" : "Update Employees Hours",    ; menu choices are "Update", "Delete",
"Delete" : "Delete An Employee",        ;        and "Quit"
"Quit" : "Return To List Of Employees"
TO CHOICE                               ; allows choice to be made
SWITCH                                  ; allows choice to be executed
   CASE (CHOICE = "Update"):            ; "Update" is chosen
      CLEARALL                          ; clears the screen
      PLAY "Jonhour"                    ; "Jonhour" script is played
      ; "Jonhour" inserts an employees hours into the "Jonhour" table
      CLEARALL                          ; clears the screen
      PLAY "Form"                       ; "Form" script is played
      ; "Form" will go to pickform and edit name, C/M, type, and branch
      CLEARALL                          ; clears the screen
      MENU {View} {Jonhour}             ; goes to menu and views "Jonhour"
      ; "Jonhour" contains JONs and hours for a selected employee
      MOVETO [Hours]                    ; moves to "Hours" field
      EDITKEY                           ; goes into edit
      WHILE (TRUE)                      ; allows user to move around table
      PROMPT "Press F10 to save changes, ESC to cancel changes, F1 to view total hours",
           REG                          ; message, name is displayed
         WAIT FIELD                     ; allows user to move around table
         UNTIL "F10", "ESC", "ENTER", "UP", "DOWN", "PGUP", "PGDN", "HOME",
             "END", "F1"                ; selected keys are functional
         SWITCH                         ; allows choice to be made
            CASE RETVAL = "ENTER" OR RETVAL = "DOWN" :
            ; "ENTER" or "DOWN" is chosen
               SWITCH                   ; allows choice to be made
                  CASE ATLAST()=TRUE :   ; if the cursor is in the
                     END                 ;       row, it will remain there
                  CASE ATLAST()<>TRUE :  ; if the cursor is not in the
                                         ;       last row
                     DOWN MOVETO[Hours] EDITKEY   ; it will move down
               ENDSWITCH                 ; switch choices end
            CASE RETVAL = "UP":         ; "UP" is chosen
               UP                       ; cursor goes up
            CASE RETVAL = "PGUP":       ; "PGUP" is chosen
               PGUP                     ; "PGUP" is executed
            CASE RETVAL = "PGDN":       ; "PGDN" is chosen
               PGDN MOVETO [Hours] EDITKEY   ; "PGDN" is executed
            CASE RETVAL = "HOME":       ; "HOME" is chosen
               HOME                     ; cursor moves to the top of the field
            CASE RETVAL = "END":        ; "END" is chosen
               END MOVETO [Hours] EDITKEY    ; cursor moves to the bottom
                                             ;of the field.
            CASE RETVAL="F1":                ;Case for viewing sum of hours.
               LEFT REC=[]                   ;Store JON in Rec.
               DO_IT!                        ;Save Jonhour table.
               PLAY "HRSUM"                  ;Play hrsum query.
               IF SUM>1728 THEN              ;Test to see if Sum is greater than 1728.  If so then
                 BEEP BEEP                   ;beep twice, show the total hours and warning.
                 @20,45 ?? "YOUR TOTAL HOURS ARE ",SUM
                 @21,45 ?? "YOU ARE OVER 1728 HOURS BY ",SUM-1728
                 @22,45 ?? "PLEASE ADJUST TO 1728"
                 SLEEP 8000
                 ELSE                        ;Otherwise just show the hours.
                 MESSAGE "TOTAL HOURS = ",SUM SLEEP 2000
               ENDIF
               CLEARALL CLEAR
               VIEW "JONHOUR"                ;View the Jonhour table.
               RIGHT LOCATE REC              ;Go to the JON field and locate the stored JON.
               MOVETO [HOURS]                ;Move to the hours field.
               EDITKEY                       ;Start editing again.
            CASE RETVAL = "ESC":        ; "ESC" is chosen
               CANCELEDIT RESET PLAY "Edit" QUITLOOP
               ; edit is canceled, screen is cleared, "Edit" script is
               ;     played, loop ends
               ; "Edit" goes back to list of employees
```

```
                CASE RETVAL = "F10":      ; "F10" is chosen
                    MENU DO_IT! PLAY "Addnew" DO_IT! CLEARALL
                    PLAY "Savehr"
                    ; "Addnew" makes a table with the edited hours
                    ; "Savehr" puts the edited hours into the "Hours" table
; goes to menu, saves the changes, plays the "Addnew" script, processes the
;       query, clears the screen, plays the "Savehr" script
            ENDSWITCH                     ; ends switch choices
        ENDWHILE                          ; ends while statement
    CASE (CHOICE = "Delete"):             ; delete is chosen
        @2,0 ?REF                         ; prints the employee name
        SHOWMENU                          ; displays a menu
        "Yes" : "Delete This Employee",   ; "Yes" and "No" are choices
        "No" : "Do Not Delete This Employee"
        TO CHOICE                         ; allows choice to be made
        SWITCH                            ; allows choice to be executed
            CASE (CHOICE = "Yes"):        ; "Yes" is chosen
                MENU {View} {Hours}       ; goes to menu, views "Hours"
                ; "Hours" table contains JONs, hours, and employees
                MOVETO [Name]             ; moves to "Name" field
                LOCATE REF                ; locates employee, REF
                WHILE retval              ; loop that will locate all REF
                SLEEP 1000                ; pauses for a second
                EDITKEY                   ; goes into edit
                DEL                       ; deletes line
                UP                        ; goes up
                MOVETO [Name]             ; moves to "Name" field
                DOWN                      ; goes down
                LOCATE NEXT REF           ; locates next employee, REF
                ENDWHILE                  ; while loop ends
                DO_IT!                    ; saves changes
                CLEARALL                  ; clears the screen
                MENU {View} {Name}        ; goes to menu, views "Name"
                ; "Name" table contains employee name, C/M status, type, office
                MOVETO [Name]             ; moves to "Name" field
                LOCATE REF                ; locates employee, REF
                EDITKEY                   ; goes into edit
                DEL                       ; deletes the line
                DO_IT!                    ; saves the changes
                CLEARALL                  ; clears the screen
                MENU {View} {People}      ; goes to menu, views "People"
                ; "People" table contains list of employees
                MOVETO [Name]             ; moves to "Name" field
                LOCATE REF                ; locates employee, REF
                EDITKEY                   ; goes into edit
                DEL                       ; deletes the line
                DO_IT!                    ; saves the changes
                RESET                     ; clears the screen
                PLAY "Edit"               ; plays the "Edit" script
                ; "Edit" goes back to the list of employees
            CASE (CHOICE = "No"):         ; "No" is chosen
                RESET PLAY "Edit"         ; clears the screen, plays "Edit"
                ; "Edit" goes back to the list of employees
        ENDSWITCH                         ; switch choices end
    CASE (CHOICE = "Quit"):               ; "Quit" is chosen
        RESET PLAY "Edit"                 ; clears everything, plays "Edit"
        ; "Edit" goes back to the list of employees
ENDSWITCH                                 ; switch choices end
```

;FORM.SC

```
MENU {View} {Name}                  ; goes to menu and views "Name"
; "Name" contains employee name, C/M status, type, and office
MOVETO [Name]                       ; moves to "Name" field
LOCATE REF                          ; locates "REF", selected employee
PICKFORM "F"                        ; goes into pickform
WHILE (TRUE)                        ; allows user to move freely around field
FOR VARI FROM 1 TO 5 STEP 1         ; assigns variables so descriptions can
                                    ;       be displayed
SWITCH                              ; allows cases to be executed
    CASE VARI = 1 :                 ; vari 1 prompts message to user
        PROMPT "Press F10 to save changes, press ESC to cancel changes",
               "Edit employee name"
    CASE VARI = 2 :                 ; vari 2 prompts message to user
        PROMPT "Press F10 to save changes, press ESC to cancel changes",
               "(C)ivilian or (M)ilitary"
    CASE VARI = 3 :                 ; vari 3 prompts message to user
        PROMPT "Press F10 to save changes, press ESC to cancel changes",
               "S & T code"
    CASE VARI = 4 :                 ; vari 4 prompts message to user
        PROMPT "Press F10 to save changes, press ESC to cancel changes",
               "Edit Branch office"
    CASE VARI = 5 :                 ; vari 5 gives user menu
        SHOWMENU                    ; displays menu
            "Save" : "Save Changes",       ; "Save" and "Cancel" are choices
            "Cancel" : "Exit Without Saving Changes"
        TO CHOICE                   ; allows choice to be made
        SWITCH                      ; allows choice to be executed
            CASE (CHOICE = "Save"):  ; "Save" is chosen
                DO_IT!                      ; saves changes
                SWITCH                      ; allows case choices to be executed
                    CASE REF = REG :        ; old name(REF) and new name(REG)
                                            ;       are equal(no change)
                    CASE REF <> REG :       ; old name(REF) and new name(REG)
                                            ;       are not equal
                        CLEARALL CLEAR      ; screen is cleared
                        MENU {View} {Hours} ; goes to menu and views "Hours"
                        ; "Hours" table contains JONs, hours, and employees
                        MOVETO [Name]       ; moves to "Name" field
                        LOCATE REF          ; locates old name(REF)
                        WHILE retval        ; while loop begins
                            SLEEP 1000      ; pauses for one second
                            EDITKEY         ; goes into edit
                            BACKSPACE BACKSPACE BACKSPACE BACKSPACE
                                            ; backspaces to erase old name
                            TYPEIN REG      ; types in new name
                            DOWN            ; moves down
                            LOCATE NEXT REF ; locates next name(REF)
                        ENDWHILE            ; ends while loop
                        DO_IT!              ; saves changes
                        CLEARALL            ; clears the screen
                        MENU {View} {People}; goes to menu and views "People"
                        ; "People" table contains a list of employees
                        MOVETO [Name]       ; moves to "Name" field
                        LOCATE REF          ; locates old name(REF)
                        EDITKEY             ; goes into edit
                        BACKSPACE BACKSPACE BACKSPACE BACKSPACE
                                            ; backspaces to erase old name
                        TYPEIN REG          ; types in new name
                        ENTER               ; enters the name
                        DO_IT!              ; saves the changes
                ENDSWITCH                   ; switch choices end
                CLEARALL VARI = 10 QUITLOOP ; clears the screen, ends the loop
            CASE (CHOICE = "Cancel"):            ; "Cancel" is chosen
                MOVETO [Name] REG = REF          ; moves to "Name" field
                                                 ; assigns REG to REF
                CANCELEDIT FORMKEY CLEARALL VARI = 10 QUITLOOP
                ; cancels the changes, goes back to the table, clears the
                ;       screen, exits from the loop
        ENDSWITCH                   ; ends choice selections
```

```
ENDSWITCH                              ; ends choice selections
EDITKEY                                ; begins editing
WAIT TABLE                             ; allows user to move freely around field
UNTIL "F10", "ESC", "ENTER", "LEFT", "RIGHT", "UP", "DOWN", "PGUP", "PGDN",
     "HOME", "END"                     ; selected keys are functional
SWITCH                                 ; choice of function able to be made
   CASE RETVAL = "ENTER" OR RETVAL = "RIGHT" OR RETVAL = "DOWN" :
      IF VARI = 1 THEN                 ; assigns REG to the name
         REG = []
      ENDIF
      DOWN                             ; cursor will go down when "Enter",
                                       ;      "Right", or"Down" is chosen
   CASE RETVAL = "UP" OR RETVAL = "LEFT" :
      UP VARI = VARI - 2               ; cursor will go up when "Up" or "Left"
                                       ;      is chosen
   CASE RETVAL ="PGUP" OR RETVAL ="PGDN" OR RETVAL ="HOME" OR RETVAL ="END":
      BEEP VARI = VARI - 1             ; "PGUP", "PGDN", "HOME", and "END"
                                       ;      can not be executed
   CASE RETVAL = "F10":                ; "F10" is chosen
      MOVETO [Name]                    ; moves to "Name" field
      REG = []                         ; assigns REG to the name
      DO_IT!                           ; saves the changes
      SWITCH                           ; allows case choices to be made
         CASE REF = REG :              ; old name(REF) and new name(REG)
                                       ;      are equal(no change)
         CASE REF <> REG :             ; old name(REF) and new name(REG)
                                       ;      are not equal
            CLEARALL CLEAR             ; screen is cleared
            MENU {View} {Hours}        ; goes to menu and views "Hours"
            ; "Hours" table contains JONs, hours, and employees
            MOVETO [Name]              ; moves to "Name" field
            LOCATE REF                 ; locates name(REF)
            WHILE retval               ; while loop begins
               SLEEP 1000              ; pauses for one second
               EDITKEY                 ; goes into edit
               BACKSPACE BACKSPACE BACKSPACE BACKSPACE
                                       ; backspaces to erase old name
               TYPEIN REG              ; types in new name(REG)
               DOWN                    ; moves down
               LOCATE NEXT REF         ; locates next name(REF)
            ENDWHILE                   ; while loop ends
            DO_IT!                     ; saves changes
            CLEARALL                   ; screen is cleared
            MENU {View} {People}       ; goes to menu and views "People"
            ; "People" table contains list of employees
            MOVETO [Name]              ; moves to "Name" field
            LOCATE REF                 ; locates name(REF)
            EDITKEY                    ; goes into edit
            BACKSPACE BACKSPACE BACKSPACE BACKSPACE
                                       ; backspaces to erase old name
            TYPEIN REG                 ; types in new name(REG)
            ENTER                      ; enters the name
            DO_IT!                     ; saves the changes
      ENDSWITCH                        ; switch choices end
      CLEARALL VARI = 10 QUITLOOP
      ; the screen is cleared, exits from loop
   CASE RETVAL = "ESC":                ; "ESC" is chosen
      MOVETO [Name] REG = REF          ; assigns REG to REF
      CANCELEDIT POPKEY CLEARALL VARI = 10 QUITLOOP
      ; changes are canceled, goes back to the table, screen is cleared,
      ;      exits from the loop
ENDSWITCH                              ; switch choices end
IF VARI < 0                            ; if vari < 0
THEN DOWN                              ; the cursor will go down
VARI = 0                               ; vari = 0
ENDIF                                  ; if statement ends
ENDFOR                                 ; for statement ends
IF VARI = 10                           ; if vari = 10
THEN                                   ; then
QUITLOOP                               ; loop will end
ENDIF                                  ; if statement ends
ENDWHILE                               ; while statement ends
```

```
;JONHOUR.SC

MENU {View} {Jonhour}          ; goes to menu, views "Jonhour"
MENU {View} {Hours}            ; goes to menu, views "Hours"
; "Jonhour" table contains JONs and hours for selected employees
; "Hours" table contains JONs, hours, and employees
MOVETO [Name]                  ; moves to "Name" field
LOCATE REF                     ; locates employee, REF
WHILE retval                   ; begins while loop
SLEEP 1000                     ; pauses for a second
MOVETO [JON]                   ; moves to "JON" field
Z = [JON]                      ; assigns "Z" to JON
MOVETO [Hours]                 ; moves to "Hours" field
S = [Hours]                    ; assigns "S" to the hours
MOVETO [Jonhour ->]            ; moves to "Jonhour" field
MOVETO [JON]                   ; moves to "JON" field
LOCATE Z                       ; locates the JON(Z)
MOVETO [Hours]                 ; moves to the "Hours" field
EDITKEY                        ; goes into edit
TYPEIN S                       ; types "S"
ENTER                          ; enters the hours
MOVETO [Hours ->]              ; moves to "Hours" table
MOVETO [Name]                  ; moves to the "Name" field
DOWN                           ; moves down
LOCATE NEXT REF                ; locates next employee, REF
ENDWHILE                       ; ends while loop
DO_IT!                         ; saves the changes
; the purpose of this script is to enter the hours of a selected employee into
;      the "Jonhour" table
```

```
;SAVEHR.SC

MENU {View} {Hours}              ; goes to menu and views "Hours" table
; "Hours" table contains JONs, employees, and hours
MOVETO [Name]                    ; moves to "Name" field
LOCATE REG                       ; locates the employee(REG)
WHILE retval                     ; while loop begins
   SLEEP 1000                    ; pauses for one second
   EDITKEY                       ; goes into edit
   DEL                           ; deletes the line
   LOCATE NEXT REG               ; locates next employee(REG)
ENDWHILE                         ; while loop ends
DO_IT!                           ; saves the changes
CLEARALL                         ; clears the screen
MENU {View} {Hours}              ; goes to menu and views "Hours" table
MENU {View} {Answer}             ; goes to menu and views "Answer" table
; "Hours" table contains JONs, employees, and hours
; "Answer" table contains JONs and hours for one employee
MOVETO [JON]                     ; moves to "JON" field
G = "Answer"                     ; assigns "G" to "Answer"
IF ISEMPTY(G) = TRUE             ; if the "Answer" table is empty
    THEN DO_IT! RESET PLAY "Edit" QUITLOOP
; then the changes are saved and the "Edit" script is played, the loop ends
; "Edit" will go to the list of employees
ENDIF                            ; if statement ends
WHILE (TRUE)                     ; while loop begins
   SLEEP 1000                    ; pauses for one second
   AA = [JON]                    ; assigns "AA" to the JON
   MOVETO [Hours]                ; moves to the "Name" field
   BB = [Hours]                  ; assigns "BB" to the hours
   EDITKEY                       ; goes into edit
   DEL                           ; deletes the line
   DO_IT!                        ; saves the changes
   MOVETO [Hours ->]             ; moves to the "Hours" table
   END                           ; moves to the end of the table
   EDITKEY                       ; goes into edit
   DOWN                          ; moves down
   MOVETO [JON]                  ; moves to the "JON" field
   TYPEIN AA                     ; types in the new JON(AA)
   MOVETO [Name]                 ; moves to the "Name" field
   TYPEIN REG                    ; types in the employees name(REG)
   MOVETO [Hours]                ; moves to the "Hours" table
   TYPEIN BB                     ; types in the hours(BB)
   DO_IT!                        ; saves the changes
   MOVETO [Answer ->]            ; moves to the "Answer" table
   MOVETO [JON]                  ; moves to the "JON" field
   R = "Answer"                  ; assigns "R" to "Answer"
   IF ISEMPTY(R) = TRUE          ; if the "Answer" table is empty
      THEN DO_IT! RESET PLAY "Edit" QUITLOOP
; then the saves will be changed, the "Edit" script is played, the loop ends
; "Edit" will go to the list of employees
   ENDIF                         ; if statement ends
   DOWN                          ; cursor moves down
ENDWHILE                         ; while loop ends
```

```
;ERASECOL.SC

DELETE "Jonhour"                ; deletes "Jonhour" script
Query                           ; query will make a table containing JONs

 Jonstabl |  Jon   |
          | Check  |
          |        |
          |        |

Endquery
DO_IT!                          ; query will be processed
RENAME "Answer" "Jonhour"       ; renames "Answer" table "Jonhour"
CLEARALL                        ; clears the screen
{Modify}                        ; chooses "Modify" function
{Restructure}                   ; chooses "Restructure"
{Jonhour}                       ; restructure "Jonhour" table
RIGHT                           ; moves to the right
DOWN                            ; moves down
"Hours"                         ; types in "Hours"
RIGHT                           ; moves to the right
"N"                             ; types in "N"
DO_IT!                          ; saves the new table structure
CLEARALL                        ; clears the screen
```

```
;HRSUM.SC

Query

 Jonhour | Hours     |
         | CALC SUM  |
         |           |
         |           |

Endquery
; the purpose of this script is to total the hours an employee has for all JONs
; "Jonhour" table contains JONs and hours for a selected employee
DO_IT!                                  ; processes the query
CLEARALL CLEAR                          ; clears the screen
MENU {View} {Answer}                    ; goes to menu and views "Answer"
Q = "Answer"                            ; assigns "Q" to "Answer" table
IF ISEMPTY(Q) = TRUE                    ; if "Answer" table is empty
     THEN SUM = 0                       ; then the SUM = 0
     ELSE SUM = [Sum of Hours]          ; if not, the SUM = value in the table
ENDIF                                   ; if statement ends
```

```
;SORTPEPL.SC

Query

 People | Name  |
        | Check |
        |       |
        |       |

Endquery

DO_IT!                             ; process the query
RENAME "Answer" "People"           ; renames new table "People"
; this query was made to alphabetize the "People" table
; "People" table contains list of employees
```

```
;ADDNEW.SC

Query

 Jonhour | JON   | Hours    |        ; "Jonhour" table contains JONs and
         | Check | Check >=0 |        ;      hours for an employee
         |       |          |
         |       |          |

Endquery

; this query is part of the "Add" division of the "Employees" script
; this query will make an answer table containing the JONs and hours for
;      a new employee
; this query creates the answer table that sends the new information to
;      the "Hours" table
```

VARIOUS PROJECTS IN DATA ANALYSIS OF SURVEILLANCE SYSTEMS

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AUGUST 10, 1990

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ELECTRO - OPTICAL SYSTEMS BRANCH

RADC/OCSA

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INTRODUCTION

During my summer internship I worked at the Rome Air Development Center (RADC) at Griffiss Air Force Base, New York from June 18th to August 10th, 1990. I worked in the Electro-Optics Systems Branch where they perform research and development of Infrared (IR) Surviellance Systems for the Air Force. During the internship I worked specifically in the Data Analysis Lab. This lab's primary function was to develop and evaluate algorithms for IR systems. The computer equipment I used consisted of a Silicon Graphics IRIS 4D/80GT, a Microvax III GPX workstation, a MAC IIci, and two IBM PC's.

When I began my internship I wanted to be able to learn and write True Basic language. To help me do this I made a flow chart of an existing True Basic program that made me become familiar with progrmming and the language. After becoming familiar with programming I wrote a True Basic program that exposed me to many different language commands and concepts. To help fellow co-workers, I developed a database of aircraft characteristics for two engineers attending Long Jump IV who required specifications on characteristics of the aircrafts participating in the test mission. My next project was to determine the maxium error alllowed for a beam to intersect the aimpoint spot on a given target. My last project was the Feedback Control Analysis intended for me to become familiar with control systems by analyzing the effects of changing the feed forward gain on the system output.

FLOW CHART AND THE PROGRAM "SHADOW"

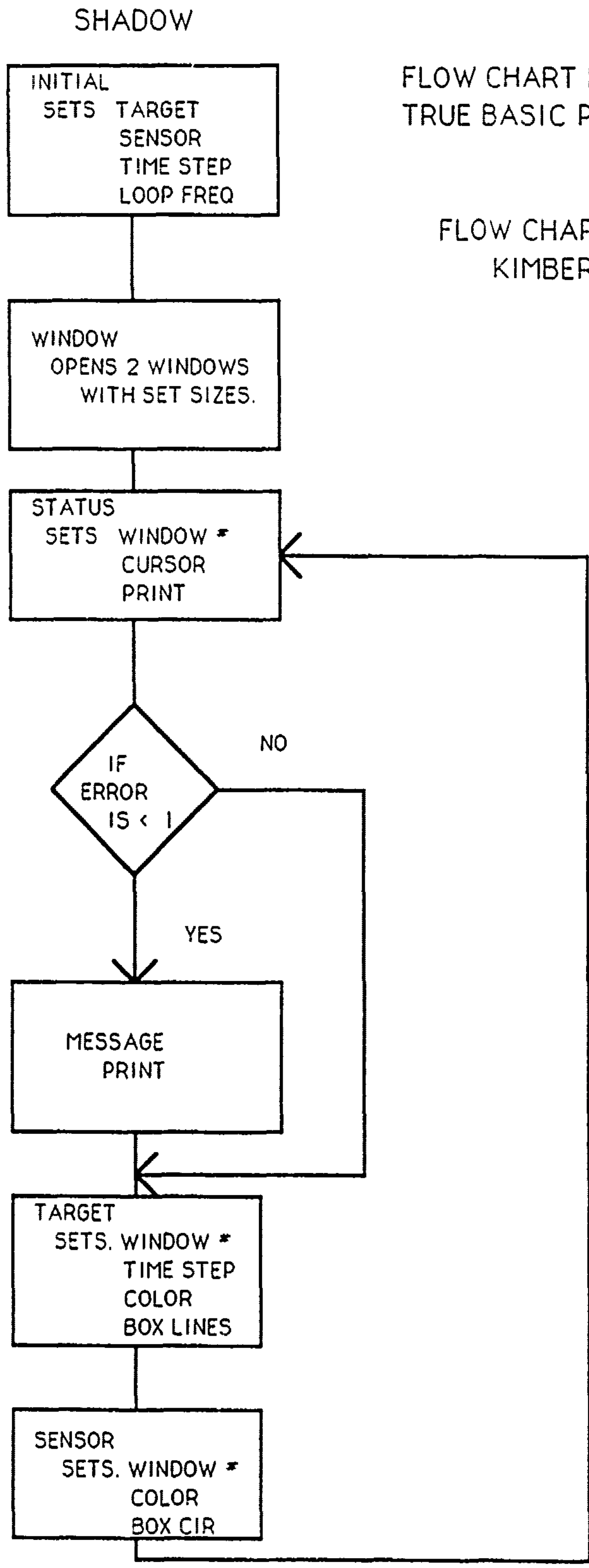
This flow chart was made using commen flow charting techniques to analyze how the program "Shadow" operates. The True Basic program "Shadow" is a test model used to implement a type 1 servo mechanism tracking algorithm. The flow chart broke down the computer code into six major functions; initial, window, status, message, target, and sensor, and one decision block.

Initial, initializes all variables used in the program including target and sensor position, time step and loop frequency. Window, allows you to open two windows of a given size on the screen. The windows are used to display the tracking algorithm. Status, determines when the message should display itself to the user. Message, displays to the user when target lock-on has occurred. The target function plots the position of the target on the screen. Sensor, plots the position of the sensor on the screen. The decision block is an if then statement that checks to determine if the error between the target position and sensor position is below a specified threshold.

This project allowed me to become familiar with programming and Basic language. This project also made me become aware of the importance of using flow charting techniques before writing a program. This flow chart was created using Claris MacDraw II on the MAC.

FLOW CHART FOR PETER CUCCI'S TRUE BASIC PROGRAM "SHADOW"

FLOW CHART WRITTEN BY:
KIMBERLY D. KING



```
!***************************************************************************
!
!                          WRITTEN BY.
!                         Peter M. Cucci
!                          June 18,1990
!
!                          For: RADC/OCSA
!
!     This program is to be used as a test model for the implemented tracking
! algorithm. It is a quick model to be used to optimize the implemented
! algorithm.
!
!***************************************************************************

CALL initial
CALL windows

DO
   CALL status
   LET t=t+1
   CALL target
   CALL sensor
   CLEAR
LOOP

SUB initial
   LET xt=-50                 !Initial target position.
   LET yt=-20
   LET xs=0                   !Initial sensor position.
   LET ys=0
   LET dt=1                   !Time step.
   LET fc=.06*(1/dt)          !Loop frequency.
   LET k1=2*pi*fc
   LET tau=1/k1
END SUB

SUB target
   window #1
   LET xt=xt+dt              !Path of target in x direction.
   LET yt=.5*xt          !Path of terget in y direction.
   get mouse xt,yt,s
   SET COLOR "red"
   BOX LINES xt-2,xt+2,yt-2,yt+2
END SUB

SUB sensor
   window #1
   SET COLOR "black"
   BOX circle xs-4,xs+4,ys-4,ys+4
   LET deltax=xt-xs               !Distance between target and sensor aimpoint.
   LET deltay=yt-ys
   LET senx=senx+tau*k1*(deltax-old_deltax)+(dt/2)*k1*(old_deltax+deltax)      !
   LET seny=seny+tau*k1*(deltay-old_deltay)+(dt/2)*k1*(old_deltay+deltay)
   LET xs=xs+senx                 !Update sensor aimpoint.
   LET ys=ys+seny
   LET old_deltax=deltax          !Store previous change in aimpoint.
   LET old_deltay=deltay
END SUB
```

```
SUB windows
   OPEN #1: screen 0,1,0,.9
   SET WINDOW -100,100,-100,100
   open #2:screen 0,1,.9,1
END SUB

SUB status
   window #2
   SET CURSOR 1,1
   print using "X ERROR: ###.######": deltax
   SET CURSOR 1,25
   PRINT using "Y ERROR: ###.######": deltay
   SET CURSOR 1,49
   PRINT "ELAPSED TIME (SEC.): ";t*dt
   window #1
   LET error=(deltax^2+deltay^2)^.5
   If error<1 then call message
END SUB

SUB message
   SET COLOR "RED"
   SET CURSOR 3,5
   print "                              TARGET LOCK ON"
   sound 1600,.1
END SUB

END
```

TRUE BASIC TRIG FUNCTION PROGRAM

This True Basic program allows the user to graphically display mathematical trig functions while inputting their own data. This program has seven major functions, one decision block and a call to the function library. The seven major functions include initial, windows, change, axis, text, user_input, and plot; and one decision block called write.

Initial, sets the value you input to equal x. Windows, opens the screen for the area of which the user wants to utilize. Change, sets the intervals (points) at which the plot would appear. Axis, draws the X andY axis and plots the marks for PI and 2PI. Text, plots the words "PI" and"2PI" at the proper designated points. User_input, prompts the user for inputs such as "Enter Max X" out to the screen and reads the value written to the screen. These prompts include max x and y, time step, trig functions, amplitude, angular frequency, and the option for a hardcopy printout. Plot, tells the computer what statement to print on the screen. The decision block, write, allows the user the option to either call copy_printer(1) which makes a hardcopy or to call change which only prints the function to the screen and doesn't make a hardcopy. The function library FNTLIB allows you to utilize all available trig functions in the library.

This program began during my first week of my internship. As the summer went on, I made many modifications. These modifications included adding a user_input and write routine which allowed my program to become user friendly. This program was created using True Basic.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!                                                            !
!                        WRITTEN BY:                         !
!                   KIMBERLY DIANE KING                      !
!                      JULY 24,1990                          !
!                                                            !
!     THIS PROGRAM ALLOWS YOU TO GRAPHICALLY DISPLAY         !
!  MATHETIMATICAL TRIG FUNCTIONS WHILE SUPPLING THE DATA     !
!  THAT YOU WISH.                                            !
!                                                            !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!


!BEFORE YOU BEGIN THIS PROGRAM YOU MUST SELECT THE CUSTOM PULL DOWN MENU,
!LOAD TB LIBRARY THEN THE FNTLIB.
OPTION NOLET
CALL USER_INPUT
CALL INITIAL
CALL WINDOWS
WINDOW #1
CALL WRITE

DO
   LIBRARY "PICTLIB*"          !ALLOWS YOU TO HAVE A HARDCOPY OF THE PLOT
   CALL CHANGE
   CALL AXIS
   CALL TEXT
   CALL PLOT
LOOP UNTIL X1>MAX

SUB INITIAL
   LET MAX=X                   !MAX=VALUE YOU INPUT
   LET X1=-X
END SUB

SUB USER_INPUT
   INPUT PROMPT "ENTER MAX X  ": X    !ALLOWS YOU TO SET OWN RANGE
   INPUT PROMPT "ENTER MAX Y  ": Y    !X AND Y SHOULD COULD HAVE THE SAME OR DIFFERENT VA
   INPUT PROMPT "ENTER DT  ": DT      !DT SHOULD HAVE A VALUE OF .1 OR .01
   PRINT "1=SIN;2=COS;3=TAN;4=CSC;5=SEC;6=COT"
   INPUT PROMPT "ENTER A FUNCTION # (1-6)  ": Z
   INPUT PROMPT "ENTER THE AMPLITUDE, C>0  ": C
   INPUT PROMPT "ENTER THE ANGULAR FREQUENCY  ": N
   INPUT PROMPT "DO YOU WANT A HARDCOPY OF THIS PLOT, 1=YES & 2=NO    ":H
END SUB

SUB WINDOWS
   OPEN #1: SCREEN 0,1,0,1
   SET WINDOW -X,X,-Y,Y
END SUB

SUB CHANGE
   LET X1= X1+DT                 !SETS INTERVAL FOR X1
END SUB

SUB TEXT
   SET COLOR "GREEN"
   ! PLOT TEXT, AT X-1, Y-1: "COS=(4*X)"
   PLOT TEXT, AT  PI,-.5: "pi"        !PLOTS "PI" AT PROPER POINT
```

```
   PLOT TEXT, AT  2*PI,-.5:"2pi"        !PLOTS "2PI" AT PROPER POINT
   SET COLOR  "MAGENTA"
END SUB

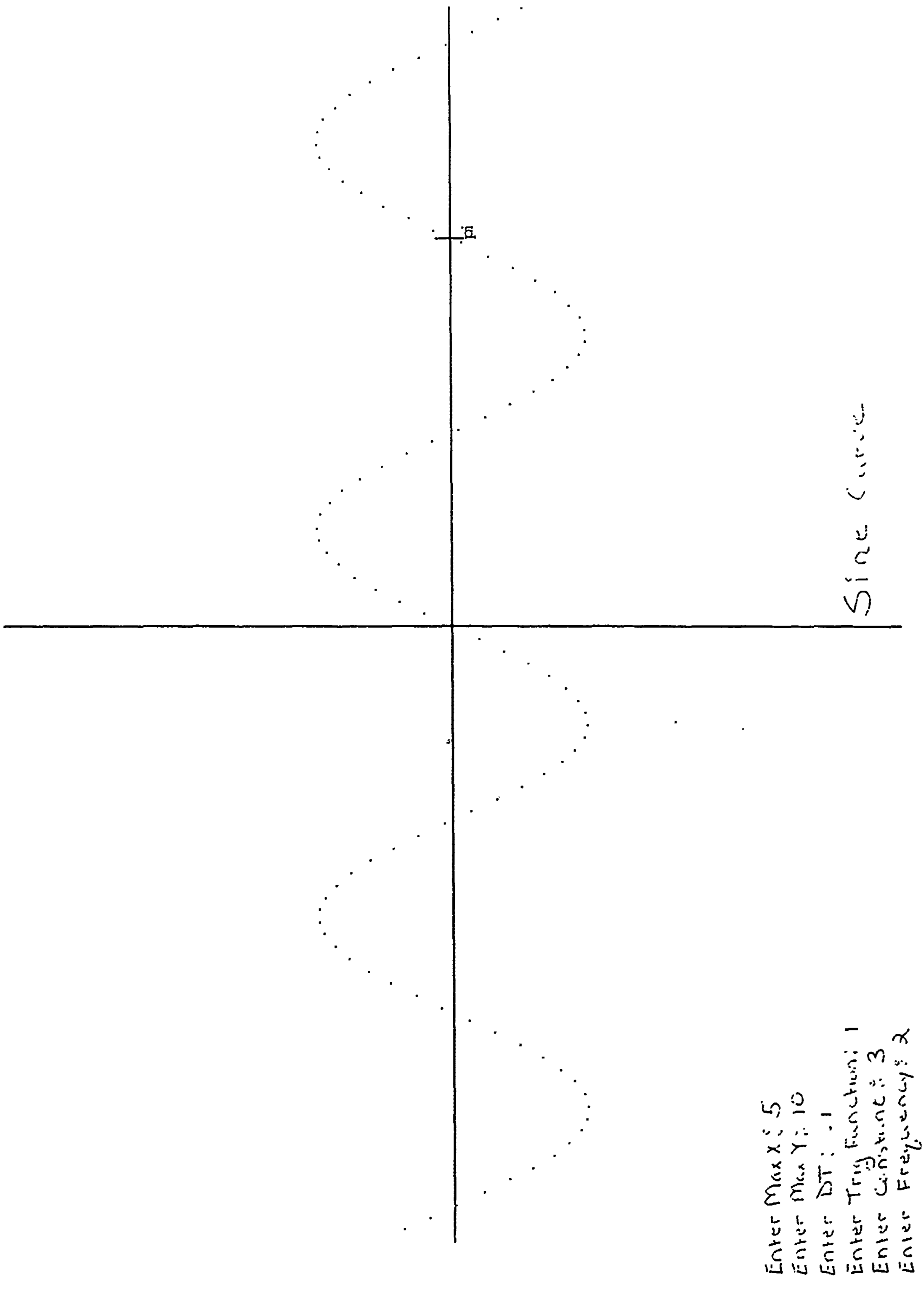
SUB PLOT
   IF Z=1 THEN
      LET Y1 =C*SIN(N*X1)
   ELSE IF Z=2 THEN
      LET Y1=C*COS(N*X1)
   ELSE IF Z=3 THEN
      LET Y1=C*TAN(N*X1)
   ELSE IF Z=4 THEN
      LET Y1=C*CSC(N*X1)
   ELSE IF Z=5 THEN
      LET Y1=C*SEC(N*X1)
   ELSE IF Z=6 THEN
      LET Y1=C*COT(N*X1)
   END IF
   PLOT LINES: X1,Y1
END SUB

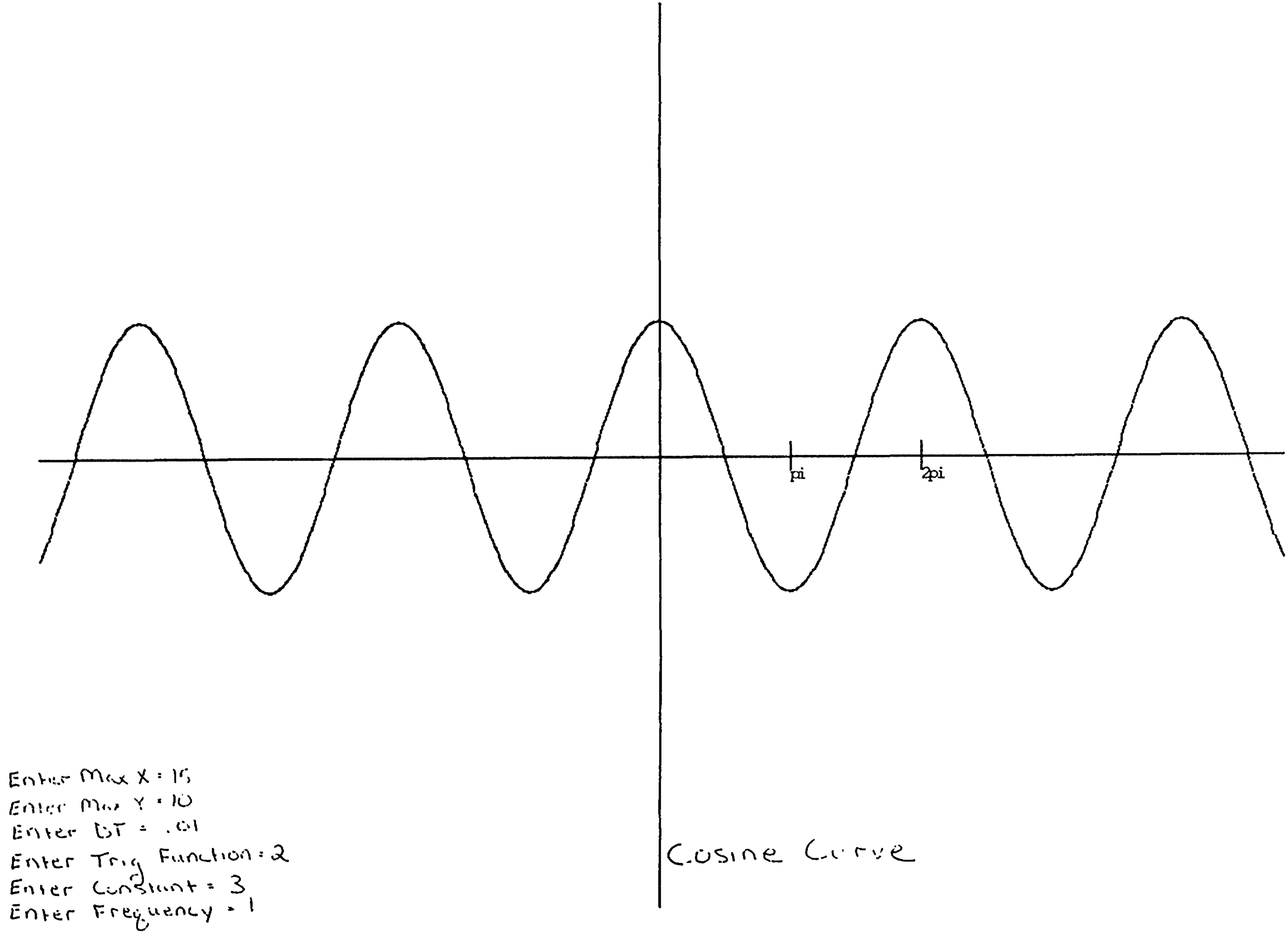
SUB WRITE
   IF H=1 THEN
      CALL COPY_PRINTER (1)
   ELSE
      CALL CHANGE
   END IF
END SUB

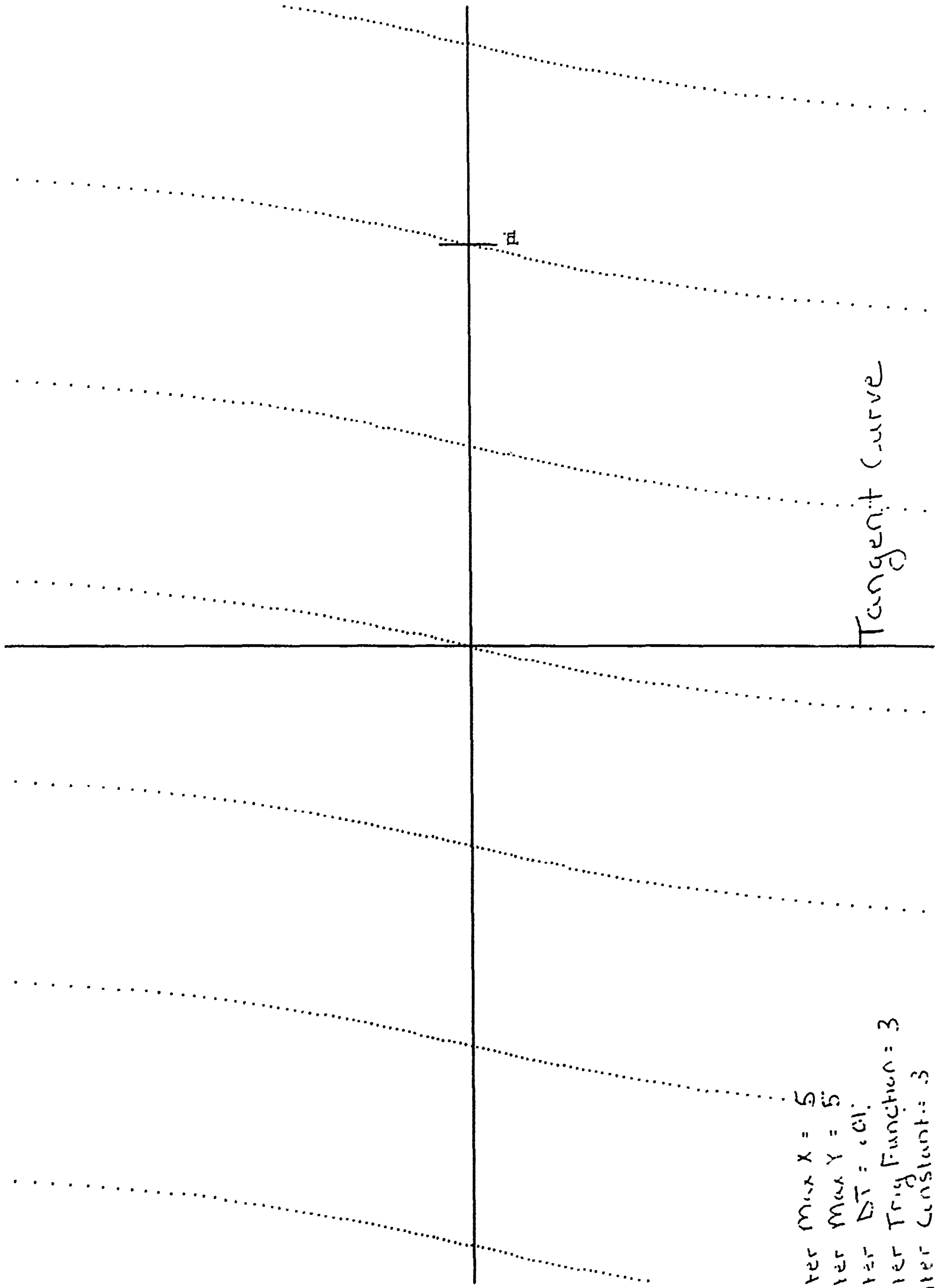
SUB AXIS
   SET COLOR  "BLACK"
   PLOT LINES: X,0; -X,0          !PLOTS X-AXIS
   PLOT LINES: 0,Y; 0,-Y          !PLOTS Y-AXIS
   PLOT LINES: PI,-.3; PI,.3      !PLOTS MARK FOR "PI"
   PLOT LINES: 2*PI,-.3; 2*PI, .3
END SUB

CALL COPY_DONE

END
```

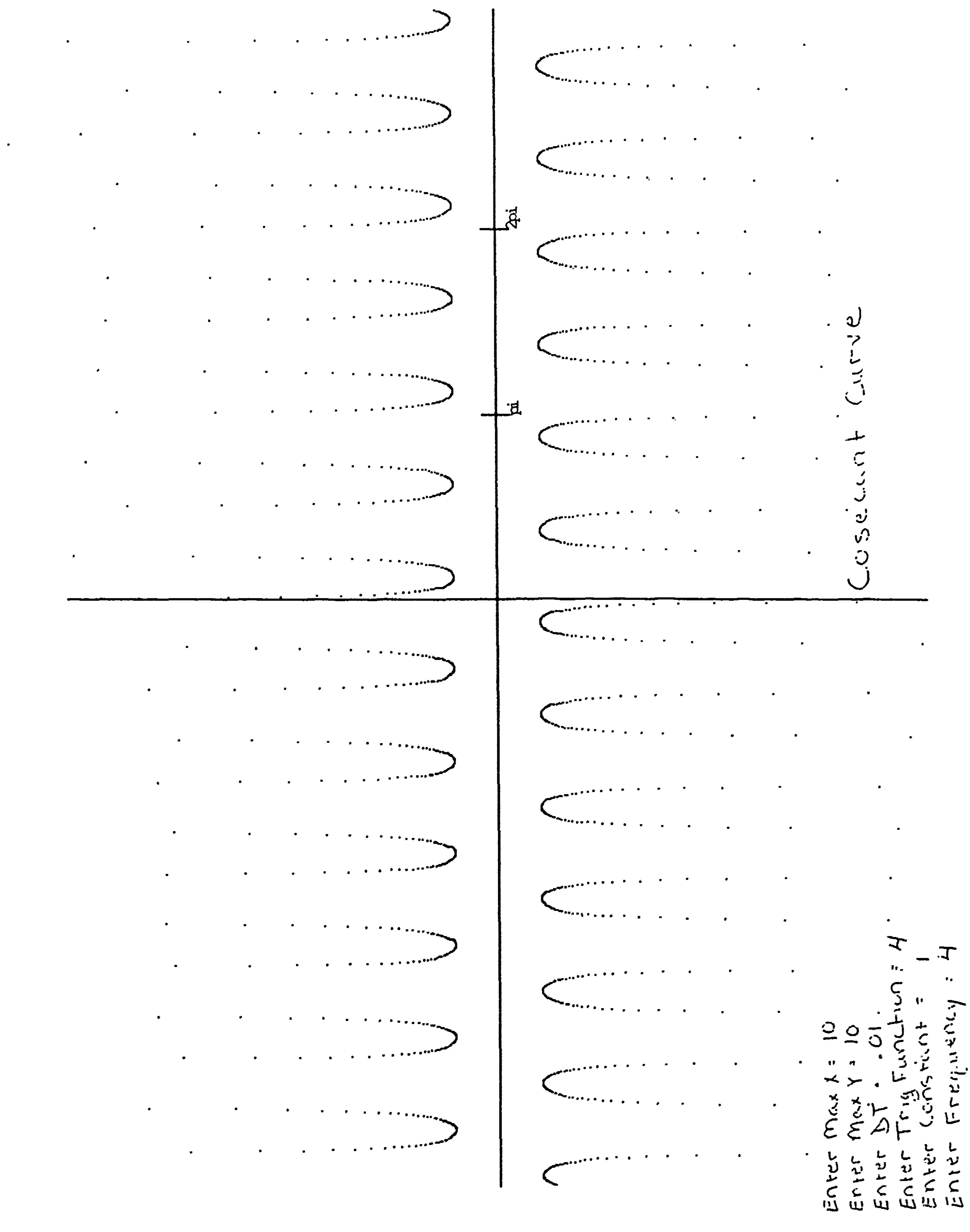

pi
Sine Curve
Enter Max X: 5
Enter Max Y: 10
Enter DT: .1
Enter Trig Function: 1
Enter Constant: 3
Enter Frequency: 2


pi
2pi
Cosine Curve
Enter Max X = 15
Enter Max Y = 10
Enter DT = .01
Enter Trig Function = 2
Enter Constant = 3
Enter Frequency = 1



Tangent Curve

Enter Max X = 5
Enter Max Y = 5
Enter DT = .01
Enter Trig Function = 3
Enter Constant = 3
Enter Frequency = 2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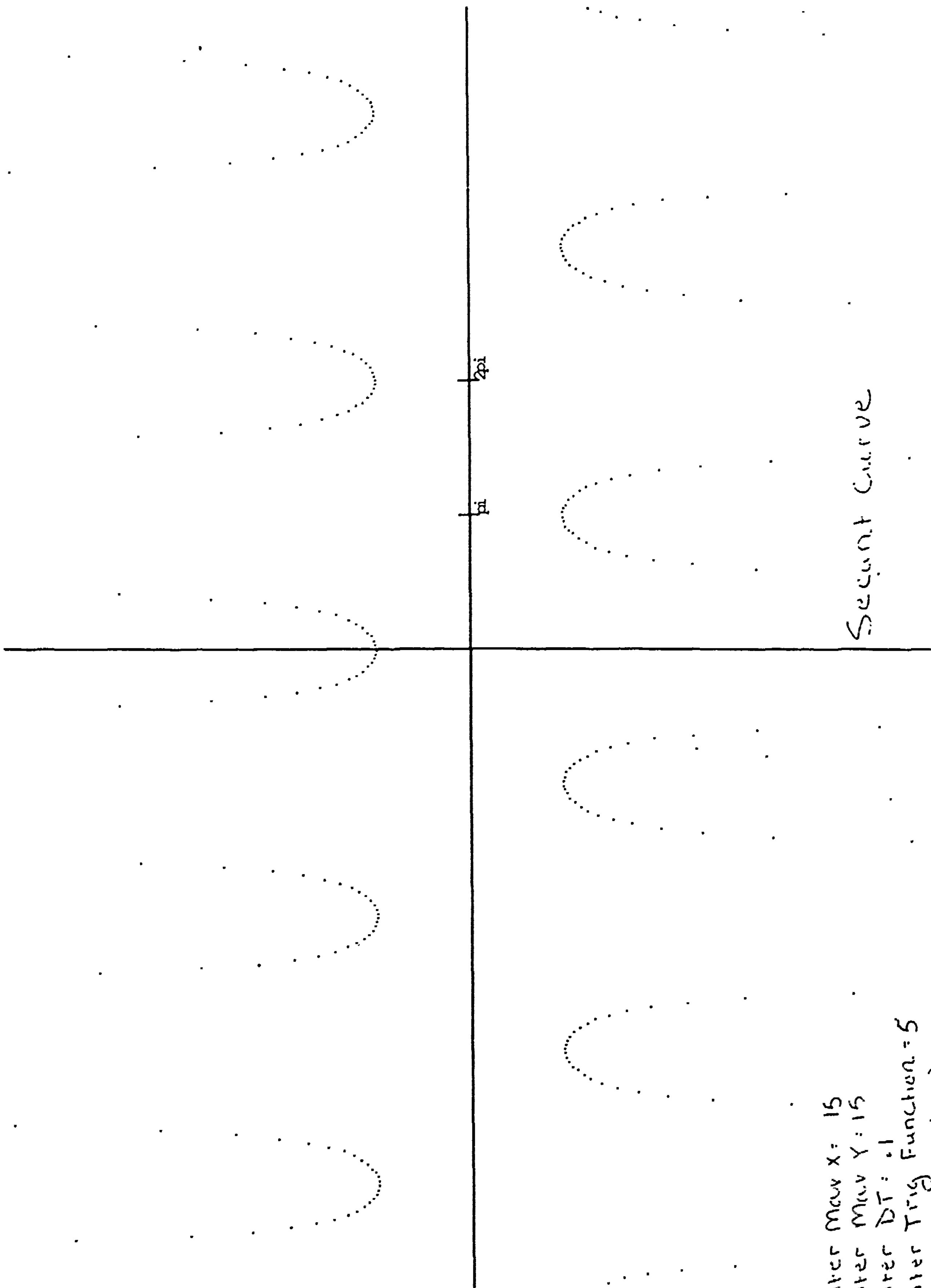
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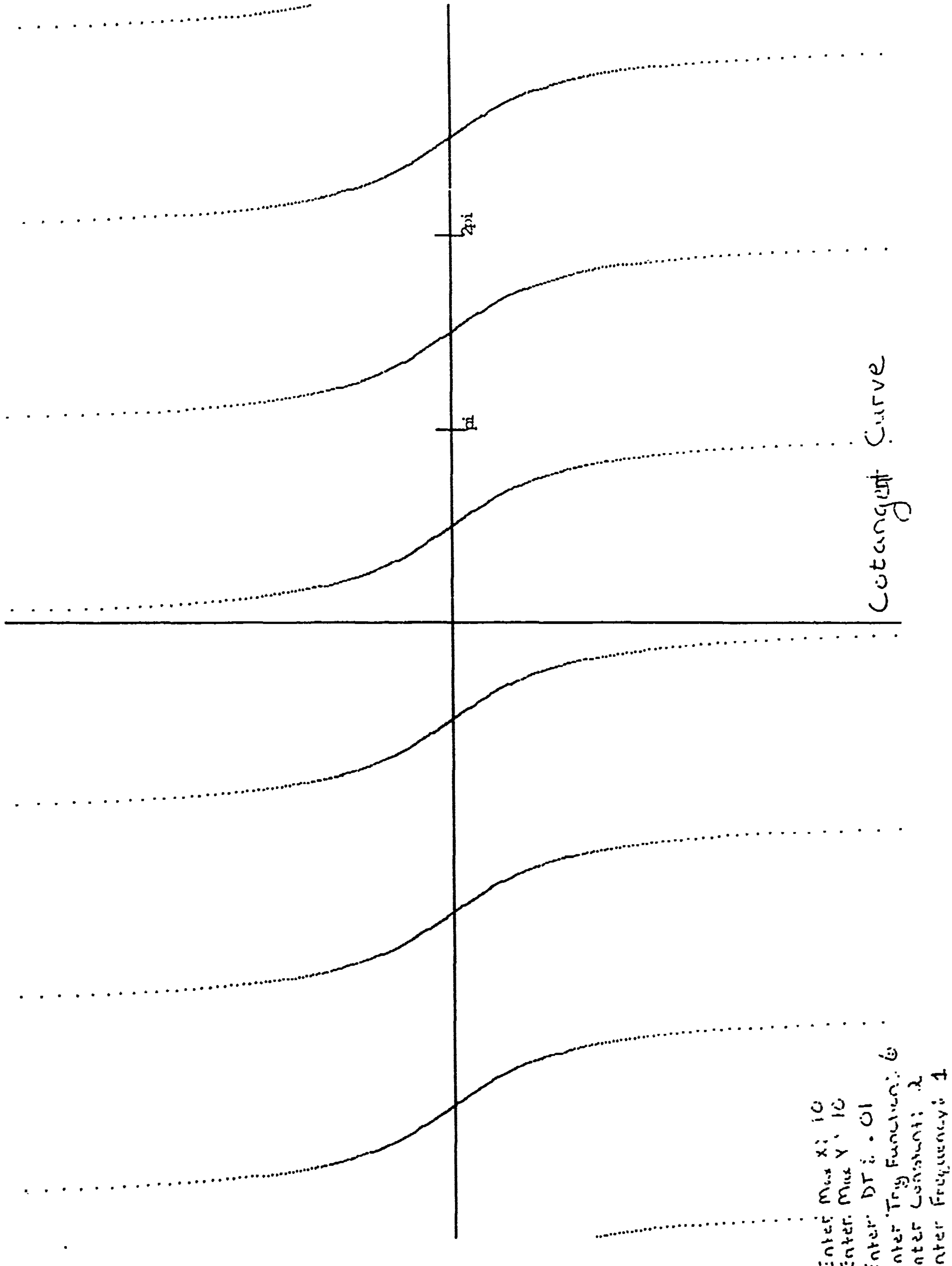
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CHARACTERISTICS OF AIRCRAFTS TO BE FLOWN AT LONG JUMP IV

This database of thirteen aircrafts participating in the test mission at Long Jump IV was developed to assist two engineers that will be attending it. Specifications on characteristics was needed to assist in accurate IR surveillance. These specifications included the type of aircraft, engine, position of engine, fuselage, weight, performance, size, and areas.

The type of aircraft specifies to the engineer if the aircraft is a fighter, support aircraft, or a bomber. The type of engines and what the engines are rated at, are useful to help identify the IR signature return of the aircraft. The position of the engines are needed to help the engineers to know where the hot spots are expected. Fuselage, tells the engineer what the structure is made of. Weight, tells you what it should weigh empty and what it should weigh with internal and external fuel and armament. Performance tells the engineer the aircrafts capabilities, such as max speed, cruising speed, landing distance, and operational radius. This can aid the engineer in determining the intensity that might be expected. Size, gives the engineers the overall dimensions of the aircraft including wing span, height, and length. Area, gives the overall area of the wings, trailing and leading edge flaps and fins.

This report allowed me to become familiar with some of the well-known aircrafts. This report was made possible with the help of Jane's All The World's Aircrafts. This report was created using Aldus PageMaker.

A-7D CORSAIR II

The A-7D is a tactical fighter version for the USAF.

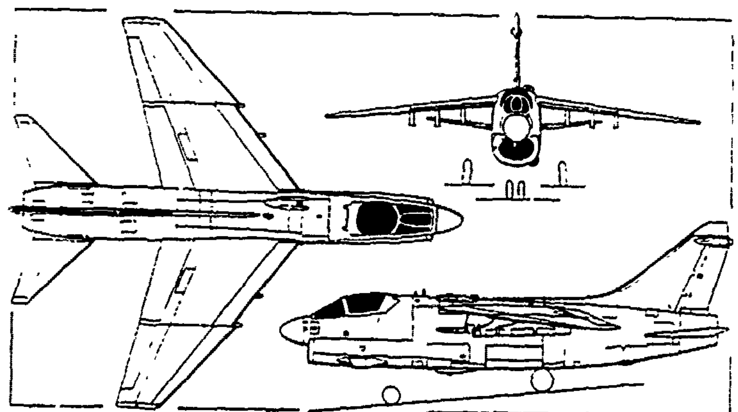
TYPE:

Subsonic single-seat tactical fighter.

ENGINE:

One Allison TF41-A-1 turbofan engine - rated at 14,250 lb (6,465 kg) st without afterburning.

POSITION OF ENGINE:



General arrangement drawing of the Vought A-7D Corsair II

FUSELAGE:

- All metal semi-monocoque structure.
- Wings are an all metal multi-spar structure with integrally stiffened aluminium alloy upper and lower skins.
- Wings have large magnesium-alloy single slotted trailing-edge flaps.

WEIGHT:

Weight empty
approx 8,165 kg (18,000 lb)

Max T-O weight
more than 19,050 kg (42,000 lb)

PERFORMANCE: (at Max T-O weight)

Max speed
606 knots (1,123 km/h)

T-O run
1,768 m (5,800 ft)

Ferry range
more than 2,450 nm (4,538 km; 2,820 mi.)

SIZE:

Wing span
11.8 m (38 ft 9 in)

Width, wings folded
7.24 m (23 ft 9 in)

Wing chord
at root - 4.72 m (15 ft 6 in)
at tip - 1.18 m (3 ft 10.25 in.)

Wing aspect ratio
4

Length overall
14.06 m (46 ft 1.5 in)

Height overall
4.88 m (16 ft)

Tailplane span
5.52 m (18 ft 1.5 in)

Wheel track
2.90 m (9 ft 6 in)

AREAS:

Wings, gross
34.83 m^2 (375 sq ft)

Ailerons (total)
1.85 m^2 (19.94 sq ft)

AREAS:

Trailing-edge flaps (total)
$4.04 \ m^2$ (43.48 sq ft)

Leading-edge flaps (total)
$4.53 \ m^2$ (48.74 sq ft)

Spoiler
$.43 \ m^2$ (4.6 sq ft)

Deflector
$.32 \ m^2$ (3.44 sq ft)

Fin
$10.33 \ m^2$ (111.2 sq ft)

Rudder
$1.40 \ m^2$ (15.04 sq ft)

Horizontal tail surfaces
$5.24 \ m^2$ (56.39 sq ft)

A-10A THUNDERBOLT

TYPE:

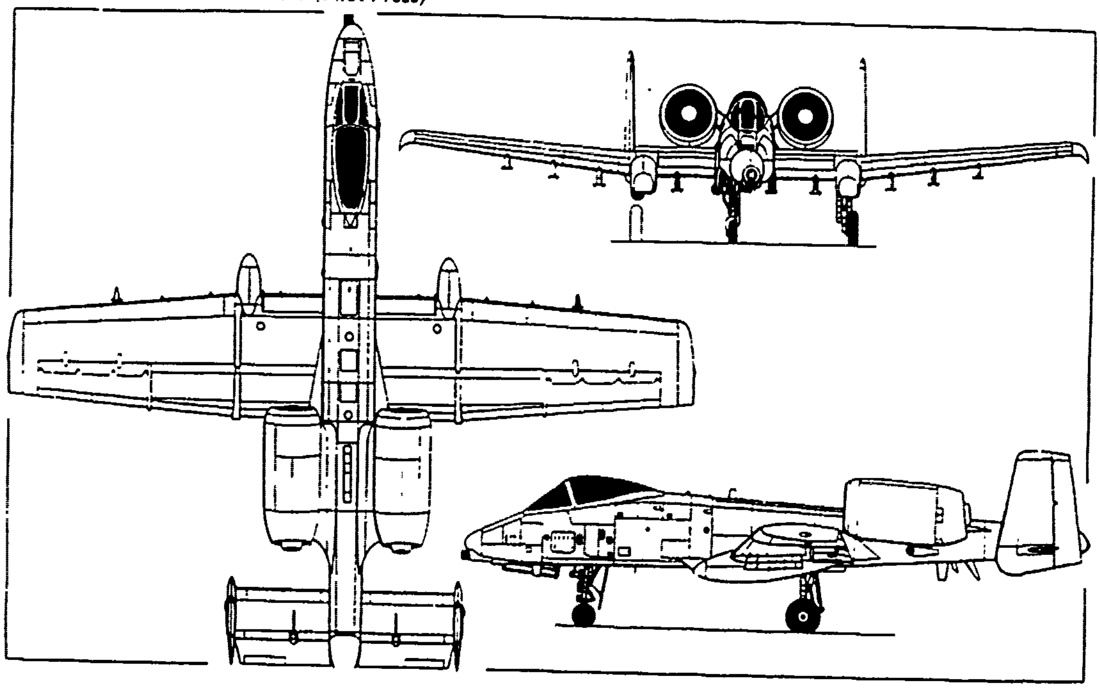
Single-seat close-support aircraft.

ENGINES:

Two General Electric TF-34-GE-100 high-bypass-ratio turbofan engines - rated at 40.3 kN (9,065 lb st).

POSITION OF ENGINES:

Fairchild A-10A Thunderbolt II. *(Pilot Press)*



FUSELAGE:

- Semi-monocoque structure, built in front, centre and aft portions.

- Tail unit is a cantilever structure.

WEIGHT:

Weight empty
11,612 kg (25,600 lb)

Max internal ordance
7,258 kg (16,000 lb)

Max T-O weight
22,680 kg (50,000 lb)

Thrust/weight ratio
0.4

PERFORMANCE: (at max T-O weight except where indicated)

Never-exceed speed
450 knots (834 km/h)

Max level speed at S/L, 'clean'
381 knots (706 km/h)

Cruising speed at S/L
300 knots (555 km/h)

Cruising speed at 1,525 m (5,000 ft)
336 knots (623 km/h)

Max rate of climb at S/L at basic design weight, 14,729 kg (32,472 lb)
1,828 m (6,000 ft)/min

T-O distance
at max T-O weight - 1,220 m (4,000 ft)
at foward airstrip weight - 442 m (1,450 ft)

Landing distance
at max T-O wieght - 610 m (2,000 ft)
at foward airstrip weight - 396 m (1,300 ft)

Operational radius, 20 min. reserve
close air support, 1.7h loiter - 250 nm (463 km; 288 mi.)
deep strike - 540 nm (1,000 km; 620 mi.)

Ferry range, headwind of 50 knots (93 km/h)
2,131 nm (3,949 km; 2,454 mi.)

SIZE:

Wing span
17.53 m (57 ft 6 in)

Length overall
16.26 m (53 ft 4 in)

Height overall
4.47 m (14 ft 8 in)

Wheel track
5.25 m (17 ft 2.5 in)

Wheelbase
5.40 m (17 ft 8.75 in)

AREA:

Wings, gross
47.01 m^2 (506 sq ft)

ROCKWELL INTERNATIONAL B-1B

Operational B-1Bs have three weapon bays which carry a varying combination of nuclear air-to-ground missiles, conventional or nuclear free-fall bombs and auxilary fuel.

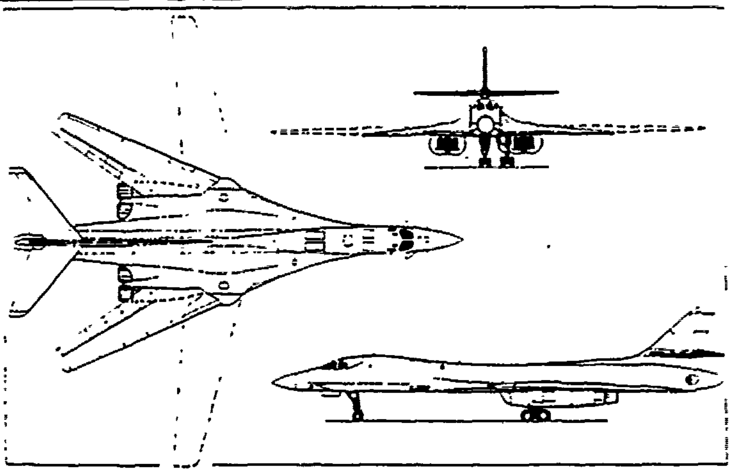
TYPE:

Low-range multi-role strategic bomber.

ENGINES:

Four General Electric F101-GE-102 augmented turbofans - rated at 136.9 kN (30,780 lb st)

POSITIONS OF ENGINES:



Rockwell International B-1B long-range multi-role strategic bomber (Pilot Press)

FUSELAGE:

- Conventional areas ruled fail-safe stressed skin structures of closely spaced frames and longerons built mainly of 2025 and 7075 aluminium alloys.

- Titanium used for engine bays and firewalls, tail support structures, rear fuselage skins, and other high heat areas.

- Nose radome of polyimide quartz.

- Dielectric panels of GFRP.

- Fin is a conventional titanium and aluminium alloy torsion box structure.

- Rudder is aluminium alloy.

WEIGHT:

Weight empty
87,090 kg (192,000 lb)

Max T-O weight
216,365 kg (477,000 lb)

Max wing loading
approx 1,194 kg/m (244.6 lb/sq ft)

PERFORMANCE:

Max level speed
approx Mach 1.25

Low-level penetration speed
approx 61 m, more than 521 knots (965 km/h)

Max unrefuelled range
approx 6,475 nm (12,000 km; 7,455 mi.)

SIZE:

Wing span
spread - 41.67 m (136 ft 8.5 in)
swept - 23.84 m (78 ft 2.5 in)

Length overall
44.81 m (147 ft)

Height overall
10.36 m (34 ft)

Tailplane span
13.67 m (44 ft 10 in)

Wheel track
4.42 m (14 ft 6 in)

Wheelbase
17.53 m (57 ft 6 in)

AREA:

Wings, gross
approx 181.2 m^2 (1,950 sq ft)st

BOEING B-52 STRATOFORTRESS

The B-52 G and the B-52 H serve with the 2nd, 7th, 42nd, 97th, 379th, 410th, 416th, Bomb Wings of the Eighth Air Force; and the 5th, 43rd, 92nd, 93rd, and 320th Bomb Wings of the Fifteenth Air Force. The 416th Bomb Wing is stationed at Griffiss Air Force Base.

TYPE:

Eight-jet heavy bomber.

ENGINES:

B-52 G has eight J57-P-43WB turbofans - rated at 61.2 kN (13,750 lb st)
B-52 H has eight Pratt and Whitney TF33-P-3 turbofans - rated at 75.6 kN (17,000 lb st).

POSITION OF ENGINES:

FUSELAGE:

All metal semi-monocoque structure.

WEIGHT:

Max T-O weight
more than 221,350 kg (488,000 lb)

PERFORMANCE:

Max level speed at high altitude
Mach .9 (516 knots; 957 km/h)

Max cruising speed at high altitude
Mach .77 (442 knots; 819 km/h)

Penetration speed at low altitude
Mach .53-.55 (353-365 knots; 652-676 km/h)

Service ceilling
16,765 m (55,000 ft)

T-O run
G - 3,050 m (10,000 ft)
H - 2,900 m (9,500 ft)

Range with max fuel, without in-flight refuelling
G - more than 6,513 nm (12,070km; 7,500 mi.)
H - more than 8,685 nm (16,093 km; 10,000 mi.)

SIZE:

Wing span
56.39 m (185 ft)

Length overall
49.05 m (160 ft 10.9 in)

Height overall
12.40 m (40 ft 8 in)

Wheel track (c/l of shock struts)
2.51 m (8 ft 3 in)

Wheelbase
15.48 m (50 ft 3 in)

AREAS:

Wing area, gross
371.6 m^2 (4,000 sq ft)

C-130H HERCULES

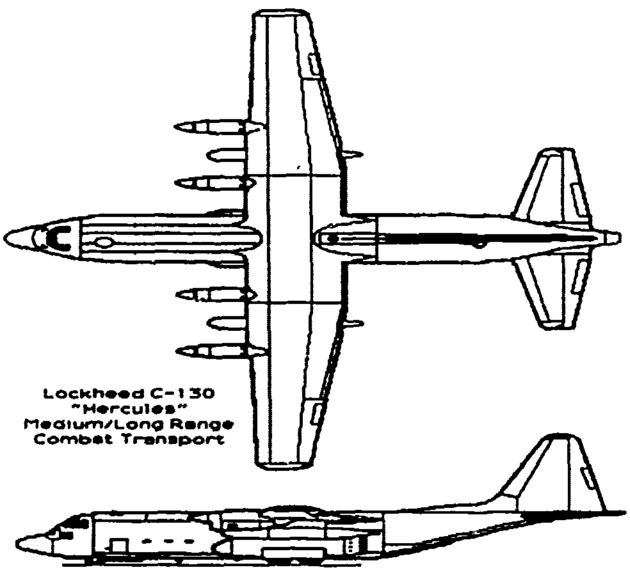
TYPE:

Medium/long-range combat transport.

ENGINES:

Four Allison T56-A-15 turbofan - rated at 3,362 kw (4,508 shp) - drive a Hamilton standard type 54H60 four blade constant-speed fully -featherering reversible-pitch propeller.

POSITIONS OF ENGINES:



FUSELAGE:

- Semi-monocoque structure of aluminium and magnesium alloys.
- Wings are all metal 2-span stressed skin structure-tampered machine skin.
- Aluminium alloy ailerons.
- Tail is cantilever all metal stressed skin structure.

WEIGHT:

Weight empty
34,686 kg (76,469 lb)

Max payload
19,356 kg (42,673 lb)

Max T-O weight
70,310 kg (155,000 lb)

Max overload T-O weight
79,380 kg (175,000 lb)

Max normal and overload landing weight
same as above T-O weights

Max zero-fuel weight, 2.5g
54,040 kg (119,142 lb)

Max wing loading
434.5 kg/m

Max power loading
5.23 kg/kw

PERFORMANCE: (at max T-O weight, unless indicated otherwise)

Max cruising speed
325 knots (602 km/h)

Econ cruising speed
300 knots (556 km/h)

Stalling speed
100 knots (185 km/h)

Max rate of climb at s/l
579 m (1,900 ft)/min

Service ceilling at 58,970 kg (130,000 lb) AUW
10,060 m (33,000 ft)

Service ceilling, one engine out, at 58,970 kg AUW
8,075 m (26,500 ft)

PERFORMANCE:

Min ground turning radius
about nosewheel - 11.28 m (37 ft)
about wingtip - 25.91 m (85 ft)

Runaway LCN at 70.310 kg (155,000 lb) AUW
asphalt - 37
concrete - 42

T-O run
1,091 m (3,580 ft)

T-O to 15 m (50 ft)
1,573 m (5,160 ft)

Range with max payload with 5% reserves and allowance for 30 min at s/l
2,046 nm (3,791 km; 2,356 mi.)

SIZE:

Wing span
40.41 m (132 ft 7 in)

Wing chord
at root - 4.88 m (16 ft)
at mean - 4.16 m (13 ft 8.5 in)

Wing aspect ratio
10.1

Length overall
29.79 m (97 ft 9 in)

Height overall
11.66 m (38 ft 3 in)

Tailplne span
16.05 m (52 ft 8 in)

Wheel track
4.35 m (14 ft 3 in)

Wheelbase
9.77 m (32 ft .75 in)

AREAS:

Wings, gross
162.12 m^2 (1,745 sq ft)

Ailerons (total)
10.22 m^2 (110 sq ft)

Trailing-edge flaps (total)
31.77 m^2 (342 sq ft)

Fin
20.90 m^2 (225 sq ft)

Rudder, incl. tab
6.97 m^2 (75 sq ft)

Tailplane
35.4 m^2 (382 sq ft)

Elevators, incl. tabs
14.4 m^2 (155 sq ft)

C-141B STARLIFTER

The C-141B is a modified version of the C-141. The C-141B has a lengthened fuselage to increase the size of the cargo compartment.

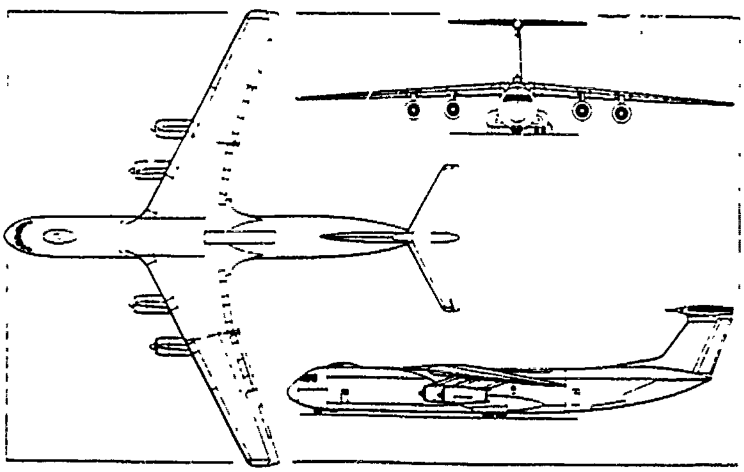
TYPE:

Four-jet long-range transport.

ENGINES:

Four Pratt and Whitney TF33-P-7 turbofan engines - rated at 93.4 kN (21,000 lb st).

POSITION OF ENGINES:



Lockheed C-141B lengthened version of the StarLifter logistics transport *(Pilot Press)*

- Mounted in underwing pods and fitted with clamshell-door thrust reversers.

FUSELAGE:

- Conventional aluminium alloy semi-monocoque structure.

WEIGHT:

Operating weight (MAC)
67,186 kg (148,120 lb)

Max T-O weight (2.5 g)
146,555 kg (323,100 lb)

WEIGHT:

Max T-O weight (2.25 g)
155,580 kg (343,000 lb)

Max zero-fuel weight (2.5 g)
99,210 kg (218,725 lb)

Max zero-fuel weight (2.25 g)
108,410 kg (239,000 lb)

Max landing weight
155,580 kg (343,000 lb)

PERFORMANCE: (at max 2.5 g T-O weight, except where indicated)

Max cruising speed
492 knots (910 km/h)

Long-range cruising speed
430 knots (796 km/h)

Max rate of climb at s/l
890 m (2,920 ft)/min

T-O to 15 m (50 ft)
1,768 m (5,800 ft)

Landing from 15 m (50 ft) at normal landing weight
1,128 m (3,700 ft)

Range with max payload
2,550 nm (4,725 km; 2,935 mi.)

Ferry range
5,550 nm (10,280 km; 6,390 mi.)

SIZE:

Wing span
48.74 m (159 ft 11 in)

Length overall
51.29 m (168 ft 3.5 in)

Height overall
11.96 m (39 ft 3 in)

F-4E PHANTOM II

Multi-role fighter for air-superiority, close support and interdiction missions with the USAF.

TYPE:

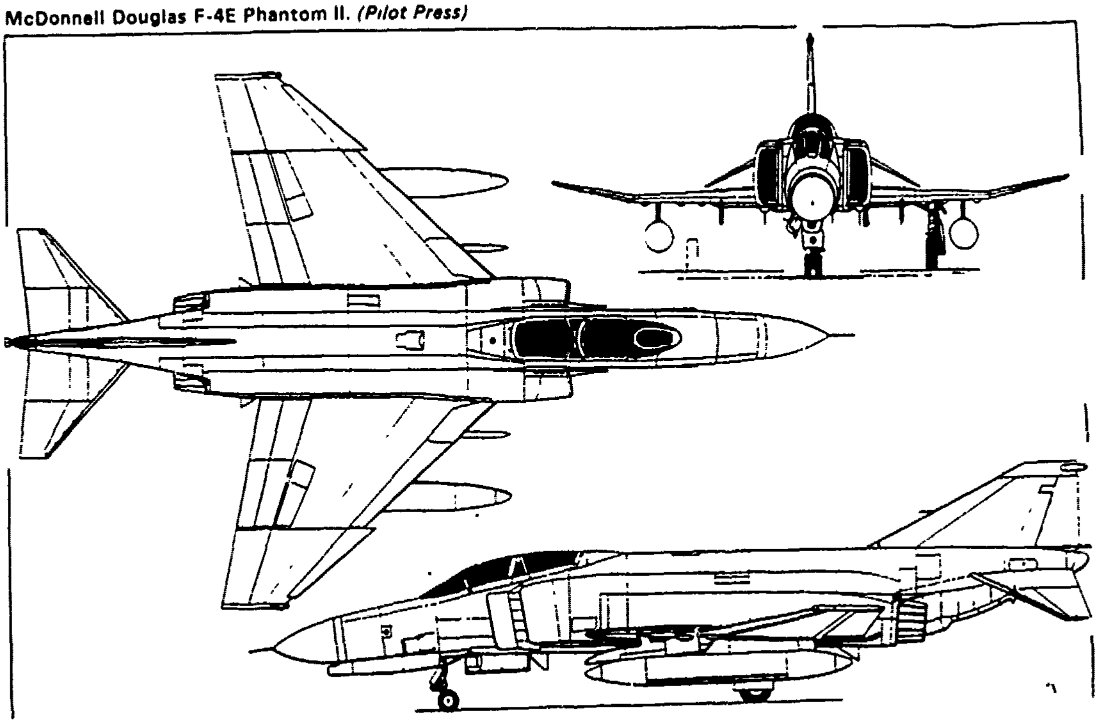
Twin-engined two-seat all-weather fighter.

ENGINES:

Two General Electric J79-GE-17A turojet engines - each rated at 79.6 kN (17,900 lb st) with afterburning.

POSTIONS OF ENGINES:

McDonnell Douglas F-4E Phantom II. *(Pilot Press)*



FUSELAGE:

- Semi-monocoque structure, built in foward, center and rear sections.

WEIGHT:

Weight empty
13,757 kg (30,328 lb)

WEIGHT:

Weight empty, basic mission
14,448 kg (31,853 lb)

Combat T-O weight
18,818 kg (41,487 lb)

Design T-O weight
26,308 kg (58,000 lb)

Max T-O weight
28,030 kg (61,765lb)

PERFORMANCE: (at 28,030 kg; 61,795 lb T-O weight)

Max level speed with external stores
over Mach 2

Average speed
496 knots (919 m/h)

Stalling speed, approach with BLC
158.6 knots (294.5 km/h)

Service ceilling (supersonic)
16,580 m (54,400 ft)

T-O run
1,338 m (4,390 ft)

Landing run (at 17,211 kg; 37,944 lb)
1,152 m (3,780 ft)

Combat radius
Area intercept - 683 nm (1,266 km; 786 mi.)
Defensive counter-air - 429 nm (795 km; 494 mi.)
Interdiction - 618 nm (1,145 km; 712 mi.)

Ferry range
1,718 nm (3,184 km;1,978 mi.)

SIZE:

Wing span
11.77 m (38 ft 7.5 in)

Width, wings folded
8.41 m (27 ft 7 in)

Length overall
19.20 m (63 ft)

Height overall
5.02 m (16 ft 5.5 in)

Wheel track
5.45 m (17 ft 10.5 in)

AREA:

Wings, gross
49.2 m^2 (530 sq ft)

F-14 TOMCAT

F-14A is a declared winner of the U.S. Navy's VFX carrier-based fighter competition.

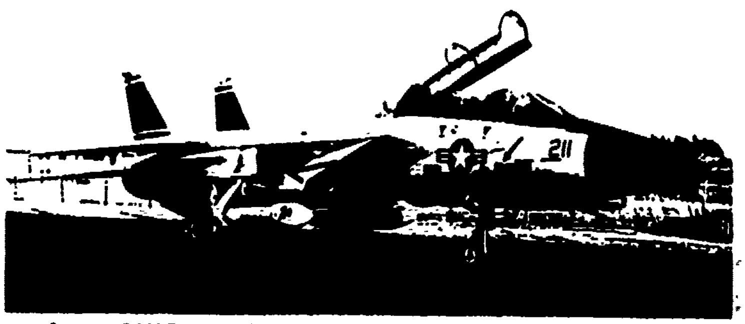
TYPE:

Two-seat carrier based multi-role fighter.

ENGINES:

Two Pratt and Whitney TF30-P-414A - rated at 93 kN (20,900 lb st)

POSITION OF ENGINES:



Grumman F-14A Tomcat of US Navy Squadron VF-31 from USS *Forresial (Alex Hav Porteous)*

FUSELAGE:

- All metal semi-monocoque structure, main longerons of titanium and light alloy stressed skin.
- The inboard wing sections are made of Ti-6AI-4V titanium alloy.
- Fins and rudders are of light alloy honeycomb sandwich.
- The all-flying multi-spar horizontal surfaces have skins of boron epoxy composite material.

WEIGHT:

Weight empty
18,191 kg (40,104 lb)

T-O weight 'clean'
26,632 kg (58,715 lb)

T-O weight with 4 sparrow
27,086 kg (59,714 lb)

T-O weight with 6 phoenix
32,098 kg (70,764 lb)

Max T-O weight
33,724 kg (74,349 lb)

Design landing weight
23,510 kg (51,830 lb)

PERFORMANCE:

Max level speed
Height - Mach 2.34 (2,485 km/h)
Low-level - Mach 1.2 (1,468 km/h)

Max cruising speed
400-550 knots (741-1,019 km/h)

Max rate of climb at s/l
over 9,140 m (30,000 ft)/min

Service ceilling
above 15,240 m (50,000 ft)

Min T-O distance
427 m (1,400 ft)

Min landing distance
884 m (2,900 ft)

Max range with external fuel
approx 1,735 nm (3,220 km; 2,000 mi.)

SIZE:

Wing span

unswept - 19.54 m (64 ft 1.5 in)
swept - 11.65 m (38 ft 2.5 in)
overswept - 10.15 m (33 ft 3.5 in)

Wing aspect ratio

7.28

Length overall

19.10 m (62 ft 8 in)

Height overall

4.88 m (16 ft)

Tailplane span

9.97 m (32 ft 8.5 in)

Wheel track

5.00 m (16 ft 5 in)

Wheelbase

7.02 m (23 ft .5 in)

AREAS:

Wings, gross

52.49 m^2 (565 sq ft)

Leading-edge slats (total)

4.29 m^2 (46.2 sq ft)

Trailing-edge flaps (total)

9.87 m^2 (106.3 sq ft)

Spoilers (total)

1.97 m^2 (21.2 sq ft)

Horizontal tail surfaces (total)

13.01 m^2 (140 sq ft)

Fins (total)

7.90 m^2 (85 sq ft)

Rudders (total)

3.06 m^2 (33 sq ft)

F-15E EAGLE

The F-15E Eagle is a two-seat dual role version capable of performing long-range, deep-interdiction, high ordnance payload air-to-ground missions in adverse weather (day or night), while retaining its power air-to-air capabilities.

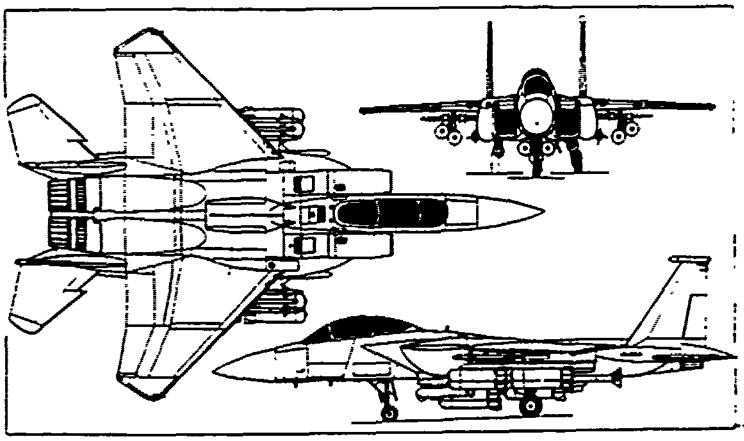
TYPE:

Two-seat dual role attack/air superiority fighter.

ENGINE:

Powered by either General Electric F110 or Pratt and Whitney F100 - rated at 266.9 kN (60,000 lb st).

POSITION OF ENGINE:



McDonnell Douglas F-15E Eagle equipped for high ordnance payload air-to-ground mission (Pilot Press)

FUSELAGE:

- Upper rear, rear fuselage keel structure, and some rear fuselage fairings incorporate superplastic-formed/diffusion bonded (SPF/DB) titanium structure.

WEIGHT:

Operating weight empty
14,379 kg (31,700 lb)

Max T-O weight
36,741 kg (81,000 lb)

PERFORMANCE:

Max level speed at height
Mach 2.5

Max combat radius
685 nm (1,270 km; 790 mi.)

SIZE:

Wing span
13.05 m (42 ft 9.75 in)

Length overall
19.43 m (63 ft 9 in)

Height overall
5.63 m (18 ft 5.5 in)

Tailplane span
8.61 m (28 ft 3 in)

Wheel track
2.75 m (9 ft .25 in)

Wheelbase
5.42 m (17 ft 9.5 in)

AREAS:

Wings, gross
56.5 m^2 (608 sq ft)

Ailerons (total)
2.46 m^2 (26.48 sq ft)

Flaps (total)
3.33 m^2 (35.84 sq ft)

Fins (total)
9.78 m^2 (105.28 sq ft)

Rudders (total)
1.85 m^2 (19.94 sq ft)

Tailplanes (total)
10.34 m^2 (111.36 sq ft)

F-16C AND F-16D FIGHTING FALCON

The F-16C and F-16D are versions of Multinational Staged Improvement Program (MSIP). MSIP expands the aircrafts growth capability to incorporate systems for ground attack and beyond-visual-range intercept missions by day and night in all weather conditions.

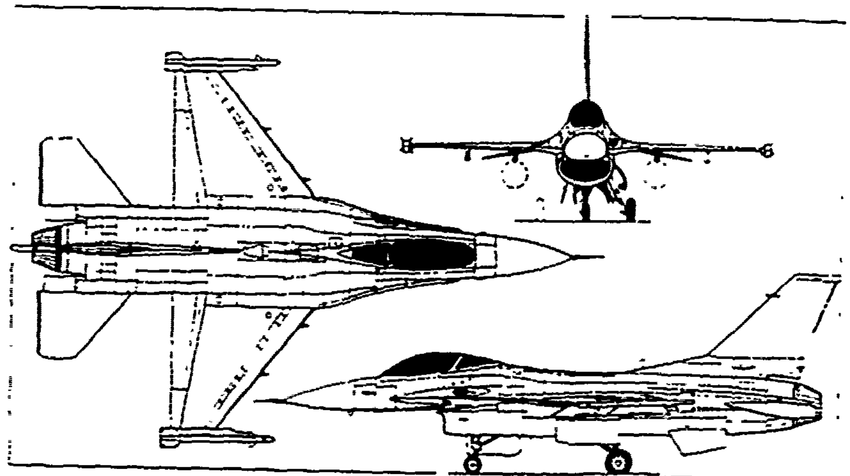
TYPE:

F-16C is a single seat day/night multi-role fighter.
F-16D is a two-seat fighter/trainer.

ENGINE:

One General Electric F110-GE-100 - rated at 122.8 kN (27,600 lb st) or
One Pratt and Whitney F-100-PW-220 - rated at 104.3 kN (23,450 lb st).

POSITION OF ENGINE:



Three-view drawing of General Dynamics F-16C Fighting Falcon (*Pilot Press*)

FUSELAGE:

- Semi-monocoque all metal structure of frames and longerons.
- Wing structure is mainly aluminium alloy.
- Fin is multi-spar multi-rib aluminium structure with graphite epoxy skins, aluminium tip and dorsal fin.
- Tailplane constructed of graphite epoxy compositelaminate skins.
- Ventral fins bonded aluminium honeycomb core with aluminium skins.

WEIGHT:

Weight empty F-16C

F100-PW-220	8,316 kg (18,335 lb)
F110-GE-100	8,663 kg (19,100 lb)

Max T-O weight

air-to-air, no external tanks

F-16C	11,372 kg (25,071 lb)
F-16D	11,114 kg (24,502 lb)

with external tanks

F-16C	19,187 kg (42,300 lb)
F-16D	17,010 kg (37,500 ib)

Wing loading

at 11,839 kg (26,100 lb) AUW

425 kg/m (87 lb/sq ft)

at 17,010 kg (37,500 lb) AUW

610 kg/m (125 lb/sq ft)

Thrust weight ratio ('clean')

1.1 to 1

PERFORMANCE:

Max level speed at 12,200 m (40,00 ft)

above Mach 2

Service ceilling

more than 15,240 m (50,000 ft)

Radius of action

more than 500 nm (925 km; 575 mi.)

Max symmetrical design g limit with full internal fuel

+9

SIZE:

Wing span over missile launchers

9.45 m (31 ft)

Wing span over missiles

10 m (32 ft 9.75 in)

SIZE:

Wing aspect ratio
3.0

Length overall
15.03 m (49 ft 4 in)

Height overall
5.09 m (16 ft 8.5 in)

Tailplane span
5.58 m (18 ft 3.75 in)

Wheel track
2.36 m (7 ft 9 in)

Wheelbase
4.00 m (13 ft 1.5 in)

AREAS:

Wings, gross
27.87 m^2 (300 sq ft)

Flaperons (total)
5.82 m^2 (62.64 sq ft)

Leading-edge flaps (total)
6.82 m^2 (73.42 sq ft)

Vertical tail surfaces (total)
5.09 m^2 (54.75 sq ft)

Rudder
1.08 m^2 (11.65 sq ft)

Horizontal tail surfaces (total)
5.92 m^2 (63.70 sq ft)

FA-18D HORNET

All FA-18Ds delivered after October 1989 will have all-weather night attack capability, including provision for pilot's night vision goggles and a Hughes Aircraft AN/AAR-50 FLIR thermal imaging navigation set (TINS) which presents TV-like images on a raster head-up display.

TYPE:

FA-18D is a two-seater naval multi-mission fighter.

ENGINES:

Two General Electric F404-GE-400 low bypass turbofans - rated at 71.2 kN (16,000 lb thrust) with afterburning.

POSITION OF ENGINES:

F/A-18D prototype of the McDonnell Douglas night attack Hornet

FUSELAGE:

- Semi-monocoque basic structure, primarily of light alloy with graphic/epoxy used for doors/panels.

- Titanium firewall between engines.

- Tail unit made primarily of graphite/epoxy over light alloy honeycomb core.

WEIGHT:

Weight empty
10,455 kg (23,050 lb)

Fighter mission T-O weight
16,651 kg (36,710 lb)

PERFORMANCE:

Max level speed
more than Mach 1.8

Max speed. intermediate power
more then Mach 1.0

Approach speed
134 knots (248 km/h)

Acceleration from 460 to 920 knots (850 to 1,705 km/h) at 10,670 m (35,000 ft)
under 2 minutes

Combat ceilling
approx 15,240 m (50,000 ft)

T-O run
less than 427 m (1,400 ft)

Combat radius
fight - more than 400 nm (700 km; 460 mi.)
attack - 575 nm (1,065 km; 662 mi.)

Ferry range, unrefuelled
more than 2,000 nm (3,706 km; 2,303 mi.)

SIZE:

Wing span
11.43 m (37 ft 6 in)

Wing span over missiles
12.31 m (40 ft 4.75 in)

Wing chord
at root - 4.04 m (13 ft 3 in)
at tip - 1.68 m (5 ft 6 in)

Wing aspect ratio
3.5

Width, wings folded
8.38 m (27 ft 6 in)

SIZE:

Length overall
17.01 m (56 ft)

Height overall
4.66 m (15 ft 3.5 in)

Tailplane span
6.58 m (21 ft 7.25 in)

Distance between fintips
3.60 m (11 ft 9.5 in)

Wheel track
3.11 m (10 ft 2.5 in)

Wheelbase
5.42 m (17 ft 9.5 in)

AREAS:

Wings, gross
36.16 m^2 (400 sq ft)

Ailerons (total)
2.27 m^2 (24.4 sq ft)

Leading-edge flaps (total)
4.50 m^2 (48.4 sq ft)

Trailing-edge flaps (total)
5.75 m^2 (61.9 sq ft)

Fins (total)
9.68 m^2 (104.2 sq ft)

Rudders (total)
1.45 m^2 (15.6 sq ft)

Tailplanes (total)
8.18 m^2 (88.1 sq ft)

FB-111A

The FB-111A is a two-seat strategic bomber version of the F-111, operating with the USAF's Strategic Air Command.

TYPE:

Two-seat long-range variable-geometry interdiction fighter.

ENGINES:

Two Pratt and Whitney TF30-P-7 turbofans - rated at 90.52 kN (20,350 lb st) with afterburning.

POSITION OF ENGINES:

General Dynamics FB-111A for USAF Strategic Air Command, carrying six underwing fuel tanks

FUSELAGE:

- Semi-monocoque structure.

- Main structural member is a T-section keel.

WEIGHT:

Weight empty
21,537 kg (47,481 lb)

Max T-O weight
approx 45,360 kg (100,000 lb)

PERFORMANCE:

Max level speed at 10,975 m (36,000 ft)
MACH 2.5

Max level speed at S/L
794 knots (1,472 km/h)

Service ceilling
more than 18,290 m (60,000 ft)

Range, with external fuel
approx 3,474 nm (6,437 km; 4,000 mi.)

SIZE:

Wing span
spread - 21.34 m (70 ft)
fully swept - 10.34 m (33 ft 11 in)
Length overall
22.40 m (73 ft 6 in)
Height overall
5.22 m (17 ft 1.4 in)

T-38 NORTHROP TALON

The T-38 is a supersonic lightweight twin-jet trainer.

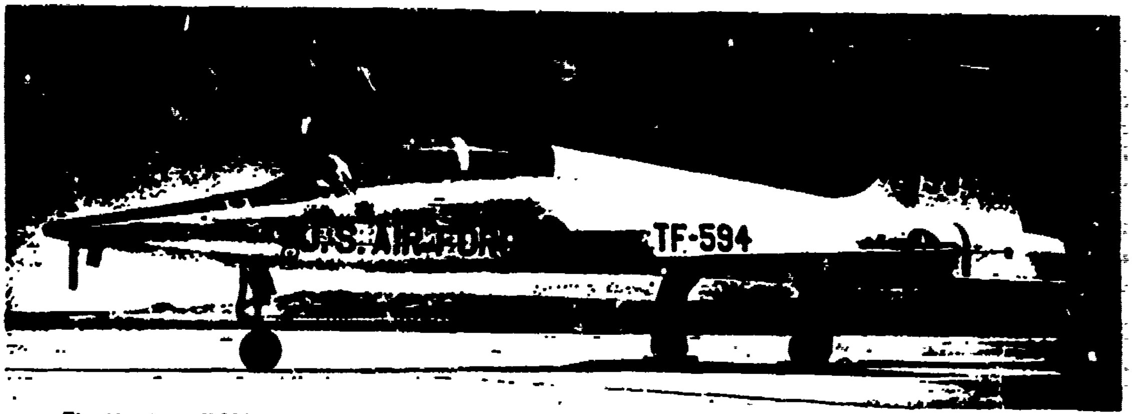
TYPE:

Two-seat supersonic basic trainer.

ENGINES:

Two General Electric J85-GE-5 turbojets with afterburners. Dry, each are rated at 2,680 lb (1,216 kg st). With afterburn, each are rated at 3,850 lb (1,748 kg lb).

POSITION OF ENGINES:



The Northrop T-38A Talon supersonic trainer (two General Electric J85 turbojet engines) (Gordon S. Williams)

FUSELAGE:

- Aluminium semi-monocoque basic structure with steel, magnesium and titanium in certain areas.

- Wings are multi-spar aluminium alloy structure with heavy plate machined skins.

- Tail unit is a cantilever all-metal structure.

WEIGHT:

Max T-O and landing weight
5,485 kg (12,093 lb)

Max power loading
1.57 lb/lb st

PERFORMANCE: (at max T-O weight, except where indicated)

Max level speed (50% fuel) at 11,000 m (36,000 ft)
above Mach 1.23

Max cruising speed at 11,000 m (36,000 ft)
above Mach .95

Stalling speed flaps extended (50% fuel)
136 knots (252 km/h) IAS

Rate of climb at S/L (50% fuel)
9,145 m (30,000 ft)/min

Service ceilling (50% fuel)
16,335 m (53,600 ft)

T-O run
756 m (2,480 ft)

SIZE:

Wing span
7.7 m (25 ft 3 in)

Wing chord
2.36 m (7 ft 9 in)

Wing aspect ratio
3.75

Length overall
14.13 m (46 ft 4.5 in)

Height overall
3.92 m (12 ft 10.5 in)

Tailplane span
4.32 m (14 ft 2 in)

Wheel track
3.28 m (10 ft 9 in)

Wheelbase
5.93 m (19 ft 5.5 in)

AREAS:

Wings, gross
15.8 m^2 (170 sq ft)

Ailerons (total)
.86 m^2 (9.24 sq ft)

Trailing edge flaps
1.77 m^2 (19 sq ft)

Fin
3.85 m^2 (41.42 sq ft)

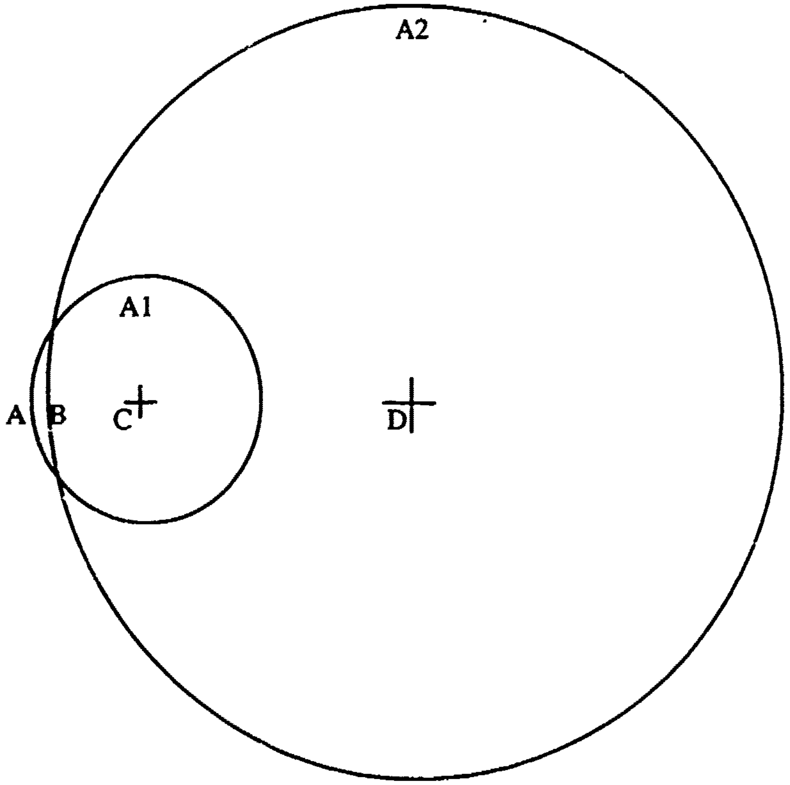
Tailplane
5.48 m^2 (59 sq ft)

MAXIMUM ERROR PROJECT

I performed a geometrical analysis on determining the maximum error allowed for a given beam to intersect the aimpoint spot on a target. First, I looked at the intersection of two circles and highlighted the area of intersection. Then I calculated at what point of intersection will 90% of area A1 fall inside the area of A2 using a straight line approximation. I then extrapolated this back to determine an error distance between lines drawn through the center. These errors were calculated at approximately 17 meters above the center of the circle and 5 meters below. This project was creatd using Aldus PageMaker.

MAXIMUM ERROR PROJECT

THIS PROJECT WAS USED TO DETERMINE THETA, POINTS AT WHICH THE TWO CIRCLES INTERSECT AND THE MAXIMUM ERROR ALLOWED FOR A BEAM TO INTERSECT THE AIMPOINT SPOT ON A GIVEN TARGET.



DIAMETER: A1 = .5M
A2 = 2M

DISTANCE: D TO B = 1M
D TO C = ?
D TO A = ?

IN ORDER FOR ME TO CALCULATE THE DISTANCE FROM D TO A OR C, I NEEDED TO CALCULATE THETA FOR THE AREA IN A1 THAT DOESN'T OVERLAP THE AREA OF A2 (SHADED AREA). THE SHADED AREA IS ONE- TENTH OF THE AREA OF A1.

THETA WAS FOUND BY USING THE FORMULA:

AREA OF THE SHADED PART = .5(R1) [THETA - SIN(THETA)] [4.1]

.5 PI(.25) = .5(.25) [THETA - SIN(THETA)]

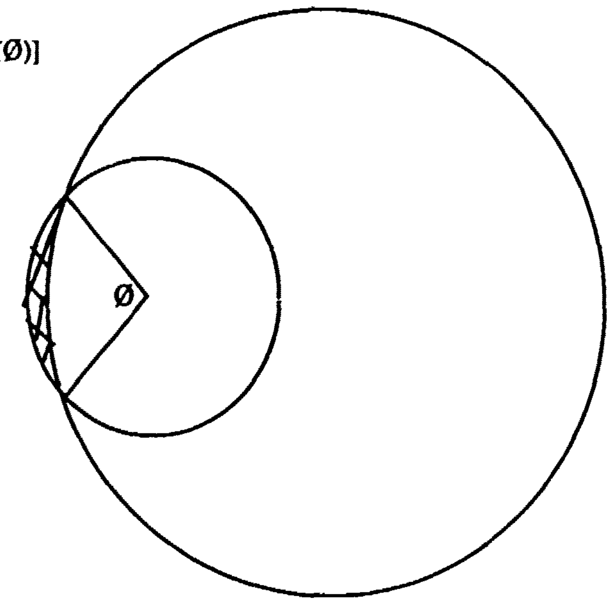
ENCLOSED, IS THE COMPUTER PROGRAM THAT I USED TO DETERMINE THETA (Ø). I USED TRUE BASIC PROGRAMMING SKILLS TO WRITE THIS PROGRAM.

I PERFORMED A STRAIGHT LINE APPROXIMATION USING THE FORMULA [4.1]:

SHADED AREA = .5R [Ø - SIN(Ø)]

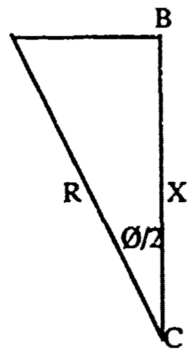
Ø = 93.163 DEGREES

Ø/2 = 46.58 DEGREES

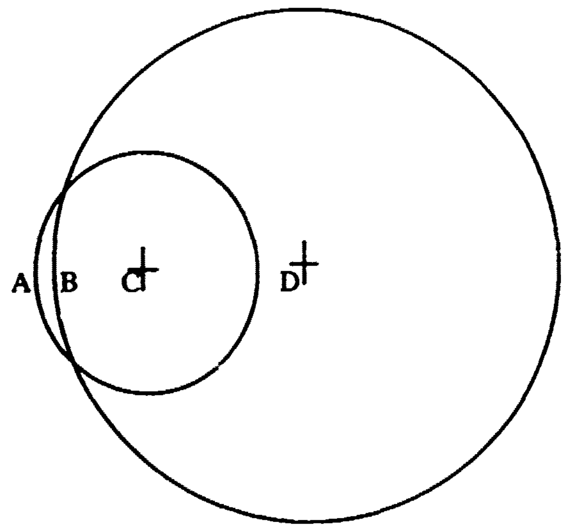


Ø/2 = 46.48 DEGREES

COSINE = $\frac{\text{ADJ}}{\text{HYP}}$ [4.2]



COSINE 46.58 = X/R (X/.25)
X = .17



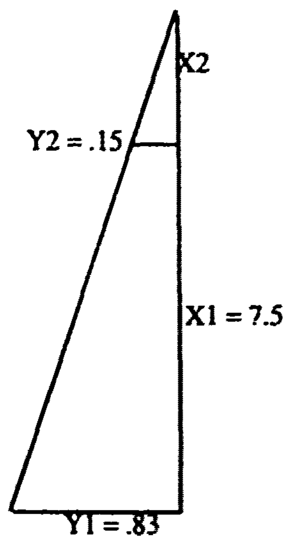
X = THE DISTANCE FROM B TO C THEREFORE, (B - X) WILL GIVE YOU THE DISTANCE OF D TO C.

C = 1 - .17
C = .83

C = IS THE CENTER OF CIRCLE A1 THEREFORE THE DISTANCE OF D TO C ADDED TO THE RADIUS OF A1 (C + .25) WILL GIVE YOU THE DISTANCE OF D TO A.

A = .83 + .25
A = 1.08

THESE NEXT PROCEDURES WILL CALCULATE THE ANGLE OF ERROR BETWEEN THE CENTER OF A2 TO THE CENTER OF A1. I WILL ALSO CALCULATE THE DISTANCE ERROR ALLOWED BETWEEN A2 AND A1. DIAGRAMS ARE NOT TO SCALE. ALL NUMERALS ARE IN METERS.



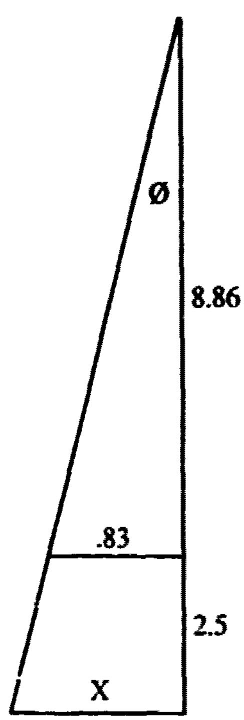
$$\frac{X2}{Y2} = \frac{X1}{Y1} \quad [4.3]$$

$$\frac{X2}{.15} = \frac{7.5}{.83}$$

$$.83(X2) = 1.125$$

$$X2 = 1.36 \text{ M}$$

$$X1 + X2 = 8.86 \text{ M}$$



$$\text{TAN } Ø = \frac{\text{OPP}}{\text{ADJ}} \quad [4.4]$$

$$\text{TAN } Ø = \frac{.83}{8.86}$$

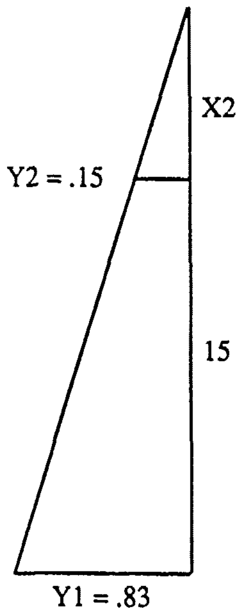
$$Ø = 5.38 \text{ DEGREES}$$

$$8.86 + 2.5 = 11.36$$

$$Ø = \frac{X}{11.36}$$

$$.09368 = \frac{X}{11.36}$$

$$X = 1.064 \text{ M}$$



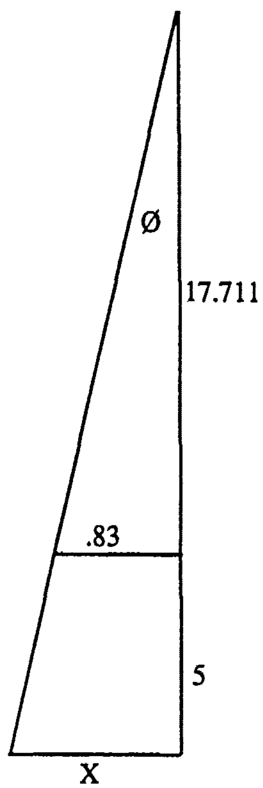
$$\frac{X2}{Y2} = \frac{X1}{Y1}$$

$$\frac{X2}{.15} = \frac{15}{.83}$$

$$.83(X2) = 2.25$$

$$X2 = 2.711 \text{ M}$$

$$X2 + X1 = 17.711 \text{ M}$$



$$\text{TAN } Ø = \frac{\text{OPP}}{\text{ADJ}}$$

$$Ø = \frac{.83}{17.711}$$

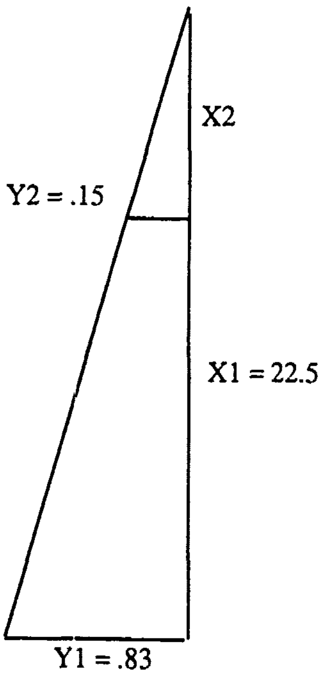
Ø = 2.69 DEGREES

$$17.711 + 5 = 22.711$$

$$Ø = \frac{X}{22.711}$$

$$.04686 = \frac{X}{22.711}$$

X = 1.064 M



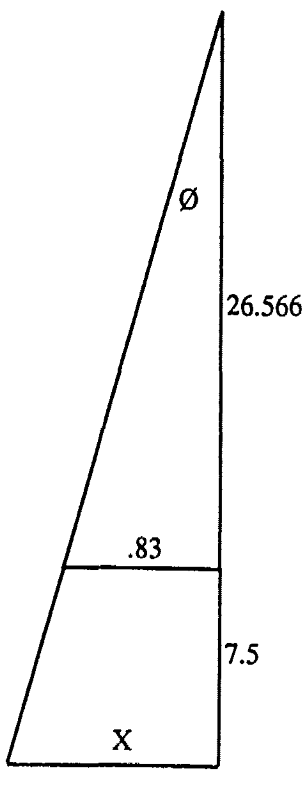
$$\frac{X2}{Y2} = \frac{X1}{Y1}$$

$$\frac{X2}{.15} = \frac{22.5}{.83}$$

$$.83(X2) = 3.375$$

$$X2 = 4.066 \text{ M}$$

$$X2 + X1 = 26.566 \text{ M}$$



$$\text{TAN } Ø = \frac{\text{OPP}}{\text{ADJ}}$$

$$\text{TAN } Ø = \frac{.83}{26.566}$$

Ø = 1.79 DEGREES

$$26.566 + 7.5 = 34.066$$

$$Ø = \frac{X}{34.066}$$

$$.031243 = \frac{X}{34.066}$$

X = 1.064 M

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!                                    !
!            WRITTEN BY:             !
!         KIMBERLY D. KING           !
!           JULY 26, 1990            !
!                                    !
!      THIS PROGRAM WAS USED TO      !
!  DETERMINE THETA FOR A PROJECT     !
!  I WAS DOING.                      !
!                                    !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!Interation on solving for ø in the equation: SHADED AREA = .5R(ø - sin ø)
LET THETA = 0.0

DO
   LET THETA = THETA + .001
   LET AREA1 = THETA - SIN(THETA)
   LET AREA2 = .2*PI
   LET DIFF = ABS(AREA1 - AREA2)
LOOP UNTIL DIFF<.001

   PRINT THETA/1.745329e-2

END
```

FEEDBACK CONTROL ANALYSIS

This project was intended for me to become familiar with control systems and how they work. The Feedback Control project has two parts: the program and the plots and the analysis. The True Basic program used to create the hardcopies of unit step, ramp, and parabolic functions and was a modified version of the program "Shadow." The analysis was used to compare my theorectical value for the steady state error with that of the computer simulation.

The True Basic program allowed me to make hardcopies of unit step, ramp, and parabolic functions plotted against the y-axis (x step) and the x-axis (time ticks). The analysis was used to analyze the effects of changing the feed forward gain on the system output. The analysis was performed through theorectical analysis and computer simulation.

First, I had to determine the block diagram and closed loop transfer function. Second, I needed to determine the range for which the system is stable. Third, I needed to determine the steady state error of the system to a unit step, ramp, and parabolic input. Lastly, I compared the theorectical analysis with the computer simulation results.

This project was important in helping me learn the basic concepts of control systems. The program and plots were created using True Basic language. The analysis was performed with the help of Schaum's Feedback and Control Systems and displayed using Aldus PageMaker.

```
!****************************************************************************
!
!                              WRITTEN BY:
!                            Peter M. Cucci
!                             June 18,1990
!
!                             For: RADC/OCSA
!
!                              MODIFIED BY:
!                            KIMBERLY D. KING
!                             JULY 31, 1990
!
!          THIS MODIFIED PROGRAM IS USED TO ANALYZE THE EFFECTS
!    OF A UNIT STEP, RAMP, AND PARABOLIC INPUTS TO THE CONTROL
!    SYSTEM.  THE ORIGINAL COPY OF THIS PROGRAM IS INCLUDED WITH
!    THE FLOWCHART SHADOW.
!
!****************************************************************************


CALL initial
CALL window
LIBRARY "PICTLIB*"
CALL COPY_PRINTER (1)

DO
   CALL axis
   CALL text
   CALL target
   CALL sensor
   CALL plot
   LET t1=t
   LET xt1=xt
   LET xs1=xs
   LET t= t+dt
LOOP UNTIL t>20

SUB initial
   !LET xt=1                    !Initial target position.
   LET xt=0
   LET xs=-2                    !Initial sensor position.
   LET dt=.03                   !Time step
   LET fc=.06*(1/dt)            !Loop frequency.
   LET k1=2*pi*fc
   LET tau=1/k1
END SUB

SUB target
   WINDOW #1
   !LET xt=1                !UNIT STEP
   !LET xt=t                !RAMP
   LET xt=5*t^2             !PARABOLIC
END SUB

SUB sensor
   WINDOW #1
   LET deltax=xt-xs              !Distance between target and sensor aimpoint.
   LET senx=senx+tau*k1*(deltax-old_deltax)+(dt/2)*k1*(old_deltax+deltax)      !
   LET xs=xs+senx                !Update sensor aimpoint.
```

```
   LET old_deltax=deltax          !Store previous change in aimpoint.
END SUB

SUB plot
   SET COLOR "BLUE"
   PLOT POINTS: t,xt
   PLOT LINES: t1,xt1;t,xt
   SET COLOR "MAGENTA"
   PLOT POINTS: t,xs
   PLOT LINES: t1,xs1;t,xs
END SUB

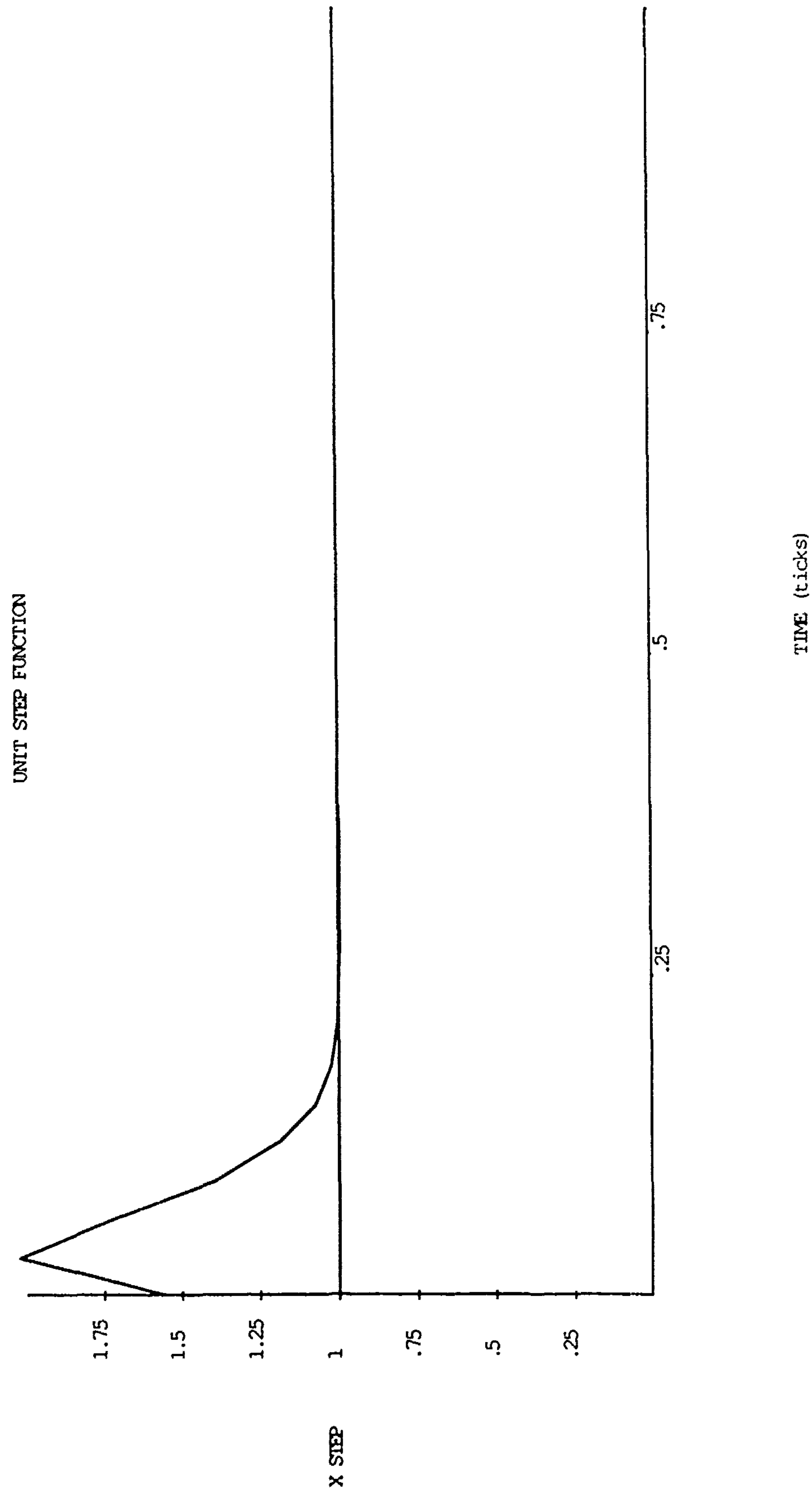
SUB axis
   SET COLOR "BLACK"
   PLOT LINES: 0,0;1,0
   PLOT LINES: 0,0;0,2
   PLOT LINES: .0025,.25;-.0025,.25
   PLOT LINES: .0025,.5;-.0025,.5
   PLOT LINES: .0025,.75;-.0025,.75
   PLOT LINES: .0025,1;-.0025,1
   PLOT LINES: .0025,1.25; -.0025,1.25
   PLOT LINES: .0025,1.5;-.0025,1.5
   PLOT LINES: .0025,1.75;-.0025,1.75
   PLOT LINES: .25,.0025;.25,-.0025
   PLOT LINES: .5,.0025;.5,-.0025
   PLOT LINES: .75,.0025;.75,-.0025
   PLOT LINES: 1,.0025;1,-.0025
END SUB

SUB text
   SET COLOR "RED"
   PLOT TEXT, AT -.05,.25:".25"
   PLOT TEXT, AT -.05,.5: ".5"
   PLOT TEXT, AT -.05,.75: ".75"
   PLOT TEXT, AT -.05,1: "1"
   PLOT TEXT, AT -.05,1.25: "1.25"
   PLOT TEXT, AT -.05,1.5: "1.5"
   PLOT TEXT, AT -.05,1.75: "1.75"
   PLOT TEXT, AT .25,-.05: ".25"
   PLOT TEXT, AT .5,-.05: ".5"
   PLOT TEXT, AT .75,-.05: ".75"
   PLOT TEXT, AT .5,-.5: "TIME (ticks)"
   PLOT TEXT, AT -.15,1: "X STEP"
   !PLOT TEXT, AT .4,2: "UNIT STEP FUNCTION"
   !PLOT TEXT, AT .4,2: "RAMP FUNCTION"
   PLOT TEXT, AT .4,2: "PARABOLIC FUNCTION"
END SUB

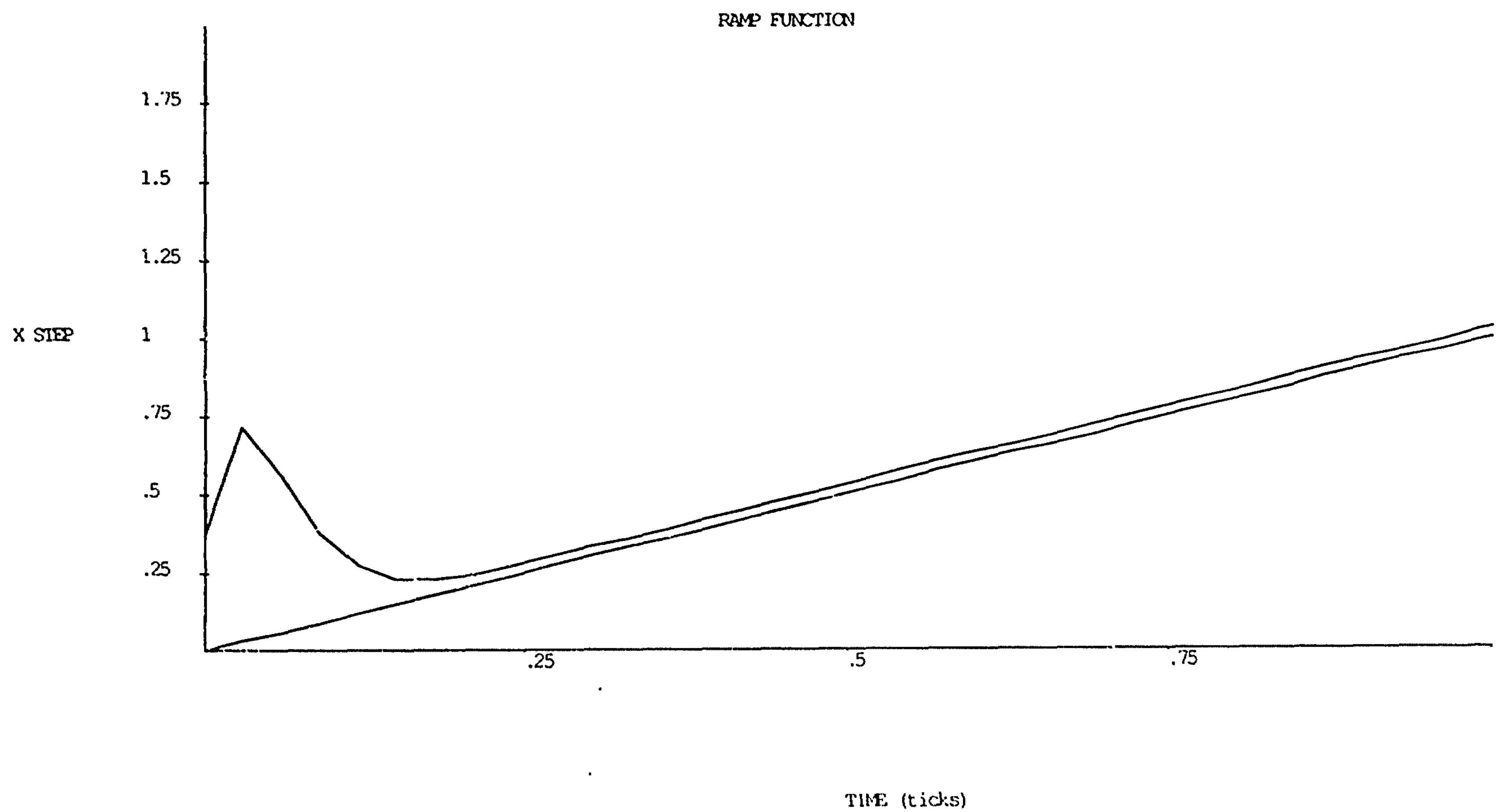
SUB window
   OPEN #1: SCREEN 0,1,0,.9
   SET WINDOW -.2,1,-1,2.25
END SUB

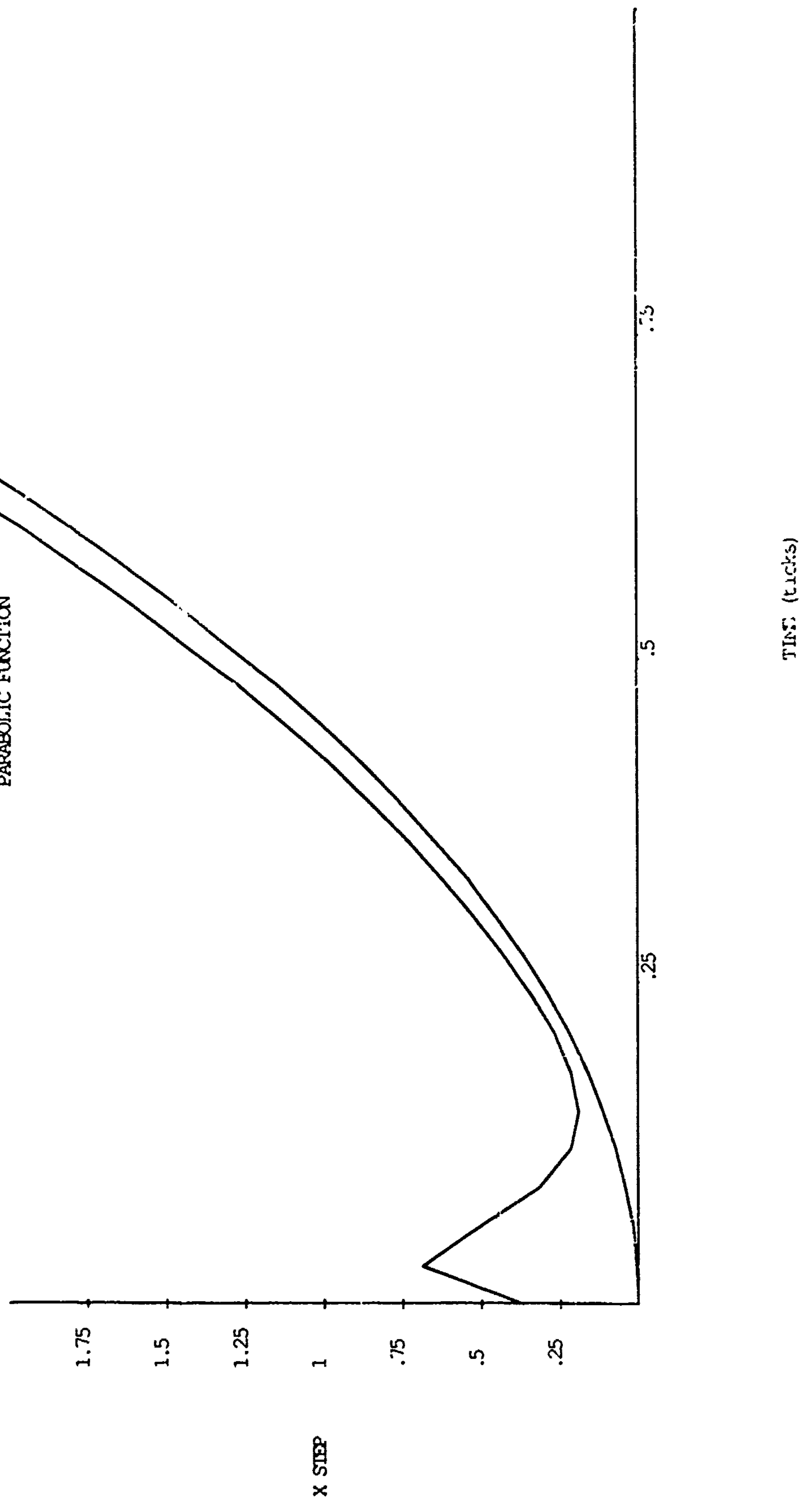
CALL COPY_DONE

END
```



UNIT STEP FUNCTION
X STEP
1.75
1.5
1.25
1
.75
.5
.25
.25
.5
.75
TIME (ticks)

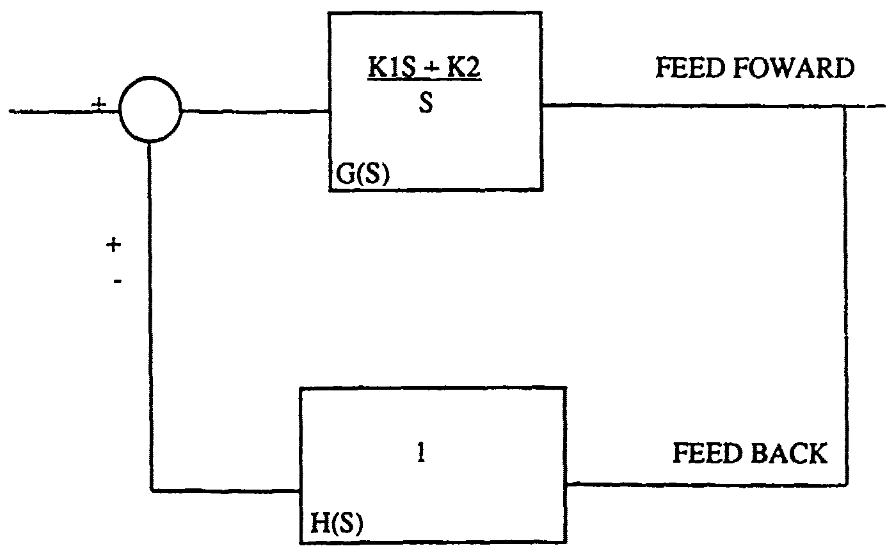

RAMP FUNCTION
X STEP
1.75
1.5
1.25
1
.75
.5
.25
.25
.5
.75
TIME (ticks)


PARABOLIC FUNCTION
X STEP
1.75
1.5
1.25
1
.75
.5
.25
.25
.5
(ticks)

FEEDBACK CONTROL ANALYSIS

OBJECTIVE: Analyze the effects of changing the feed foward gain on the system output. The analysis will be performed through theorectical analysis and computer simulation.

STEP 1: Determine the block diagram and closed loop transfer function for the control system that Pete implemented on a MAC.



CLOSED LOOP TRANSFER FUNCTION:

$$T(S) = \frac{G(S)}{1 + G(S)H(S)}$$

$$= \frac{\dfrac{K1S + K2}{S}}{1 + \dfrac{(K1S + K2)}{S}(1)}$$

$$= \frac{K1S + K2}{S + K1S + K2}$$

$$\boxed{= \frac{K1S + K2}{S(K1 + 1) + K2}} \qquad [5.1]$$

The transfer function is in Laplace Domain.

The denominator is a characteristic equation.

STEP 2: Determine the range of the feed forward gain for which the system is stable.

RANGE OF K FOR WHICH THE SYSTEM IS STABLE.

This is found by using the characteristic equation: $S1\ (K1 + 1) + K2$ [5.2]

$$\begin{array}{l|l} S1 & K1 + 1 > 0 \\ S0 & K2 \end{array}$$

$K1 > -1$ and $K2 > 0$

OR

$K1 < -1$ and $K2$

This was done by using the Routh's criterion for stablity.

<u>STEP 3:</u> Determine the steady state error of the system for a unit step, ramp, and parabolic input.

UNIT STEP (position error constant)

$$Kp = \lim_{s \to 0} G(s) \qquad [5.3]$$

$$Kp = \lim_{s \to 0} \frac{K1S + K2}{S} \qquad [5.4]$$

$$Kp = \frac{K2}{0}$$

$$\mathbf{Kp = (\infty)}$$

Steady-State error = $e(\infty)$

$$e(\infty) = \frac{1}{1 + Kp} \qquad [5.5]$$

$$e(\infty) = \frac{1}{1 + \infty}$$

$$\mathbf{e(\infty) = 0}$$

RAMP (velocity error constant)

$$Kv = \lim_{s \to 0} s\,G(S) \qquad [5.6]$$

$$Kv = \lim_{s \to 0} \frac{S\,(K1S + K2)}{S} \qquad [5.7]$$

$$\mathbf{Kv = K2}$$

Steady-State error = $e(\infty)$

$$e(\infty) = \frac{1}{Kv} \qquad [5.8]$$

$$e(\infty) = \frac{1}{K2}$$

K2 = 2*pi*fc [5.9]

fc = .06 *(1/.03) [5.10]

fc = 2

K2 = 2*pi*2

K2 = 12.6

$$\frac{1}{K2} = .08$$

$$\mathbf{e(\infty) = .08}$$

PARABOLA (acceleration error constant)

$$Ka = \lim_{s \to 0} S^2G(S) \qquad [5.11]$$

$$Ka = \lim_{s \to 0} \frac{S^2(K1S + K2)}{S} \qquad [5.12]$$

$$Ka = K1S^2 + K2S$$

$$\mathbf{Ka = 0}$$

Steady-State error = $e(\infty)$

$$e(\infty) = \frac{1}{Ka} \qquad [5.13]$$

$$e(\infty) = \frac{1}{0}$$

$$e(\infty) = \infty$$

<u>**STEP 4:**</u> **Compare the theorectical analysis with the computer simulation. Do they agree? Modified the True Basic program "SHADOW" to allow me to create and make hardcopies of unit step, ramp, and parabolic functions.**

UNIT STEP (position error constant)

AGREES

The theorectical value and the computer simulation value both agree that the steady state error should be zero (0).

RAMP (velocity error constant)

DOESN'T AGREE

The steady state error has a finite value, which agrees with the calculations. But the value doesn't agree numerically because the closed loop equation [5.1] may not contain all dynamic properities of a real system.

PARABOLIC (acceleration error constant)

AGREE

The theorectical value and the computer simulation value both agree that the steady state error should be infinite(∞).

NETWORK PROCESSING ELEMENT TEST AND EVALUATION

KATHRYN H. LEE

ROME AIR DEVELOPMENT CENTER
(R. A. D. C.) / D. C. L. D.

DAN HAGUE, MENTOR

AUGUST 10, 1990

Acknowledgements

I would like to thank those individuals involved in the United States Air Force Scientific Apprenticeship Program. Mr. Dan Hague was both helpful and inspirational throughout the entire program, offering his help an dadvice as needed. Captain John Colombi and Dr. John Evanoswky offered their guidance and support when required. Captain Colombi was extremely helpful in getting my project started and assisting Mr. Hague with pointing me in the right direction. I enjoyed working with everyone in the Network Design Lab and am thankful to the people responsible for making this summer one of the greatest experiences in my life.

I would also like to thank Brian Millar, Rich Chmielewski, and Jim Carrig for their time and support. They took time out of their busy schedules to offer their help. You guys are truly the best, I don't know what I would have done without all of you.

Network Processing Element
Test and Evaluation

There are several functions and responsibilities of the Network Design Lab at R.A.D.C. (Rome Air Development Center). One of which is to perform several tasks using the SUN workstations. The SUN workstation is a high performance, bitmapped workstation. The SUNOS Operating System provides:

- a host of software as a base level package;
- support for C and assembler languages;
- tools for software application;
- utilities for performing statistical text processing and for document preparation;
- a shared library faculty;
- support for interprocess communication and local networking; and,
- a user interface package based on overlapping windows and a comprehensive library of graphics (SUN Microsystems, 3).

Each of these workstations are connected by a network which allows you to use other machines while logged in at your own machine. Networks are commonly referred to as LANS (Local Area Networks), which range over a small area, and communicate to one another using a network protocol; a shared network language.

As part of my summer United States Air Force Scientific Apprenticeship Project, I was asked to write a C program (Appendix 1 - 3). C is a general-purpose language, originally designed for the UNIX Operating System (Kerningham, 9) and is the base for the SUNOS Operating System. The program was designed to listen for a TCP connection. Once a connection was heard, the program would call

the notify function and read in one - hundred lines containing one - hundred twenty - eight pixels in each line. Using the RasterOp routines, found within the Pixrect graphics library, the image was displayed on the SUN workstation. The image was written upon a canvas that contained a colormap and a frame. The Pixrect graphics library uses the RasterOp routines to manipulate arrays of pixels on the screen (SUN Microsystems, 3). The program would read in one - hundred twenty - eight pixels at a time if a TCP connection was heard and read in the red, green, and, blue values from that array of pixels. There was a total of two-hundred fifty-six colors that could be displayed on the image using the SUN. This allowed for a grayscale and color version to be displayed depending upon the pallete sent over from the TCP. After completion of the program, a second program (Appendix 4 - 6) was written to display the image two times as big. The clearness of the image decreased when the image became larger, due to the fact the pixels doubled in size. The image could be seen and identified, but it was not as sharp since an array of one - hundred twenty - eight by one - hundred was being sent over by the TCP and the replication of the image on the SUN was not the same as the PC. The image was very small in comparison. In order to execute the program the name of the makefile needed to be typed and the connection would close when the socket was disconnected by either the TCP or the SUN.

The program itself was part of a project started by Jim Carrig, an Electrial Engineer from Syracuse University. Throughout the summer, he had been working on several programs that would display an image on the PC. He wrote the function in my program that would listen for the socket connection and return the socket (sd). Mr. Carrig wrote a grayscale and color version, along with other

programs that altered in size. Eventually, he developed a C program to display an image on a PC and send that image to another PC and display that same image there. Although, the time required to display the image on the two PC's took a significant amount of time. Therefore, implementation of the same concept on the SUNOS Operating System proved to be substaintially faster.

Prior to this, I worked on another project that involved two rigs, CISCO and PROTEON. Several tests were made on both rigs and the results were stored in the SUNOS Operating System. Using Symphony and Freelance, the data was organized and eventually graphed to display the results of both rigs. Symphony is a flexible program that combines five capabilities:

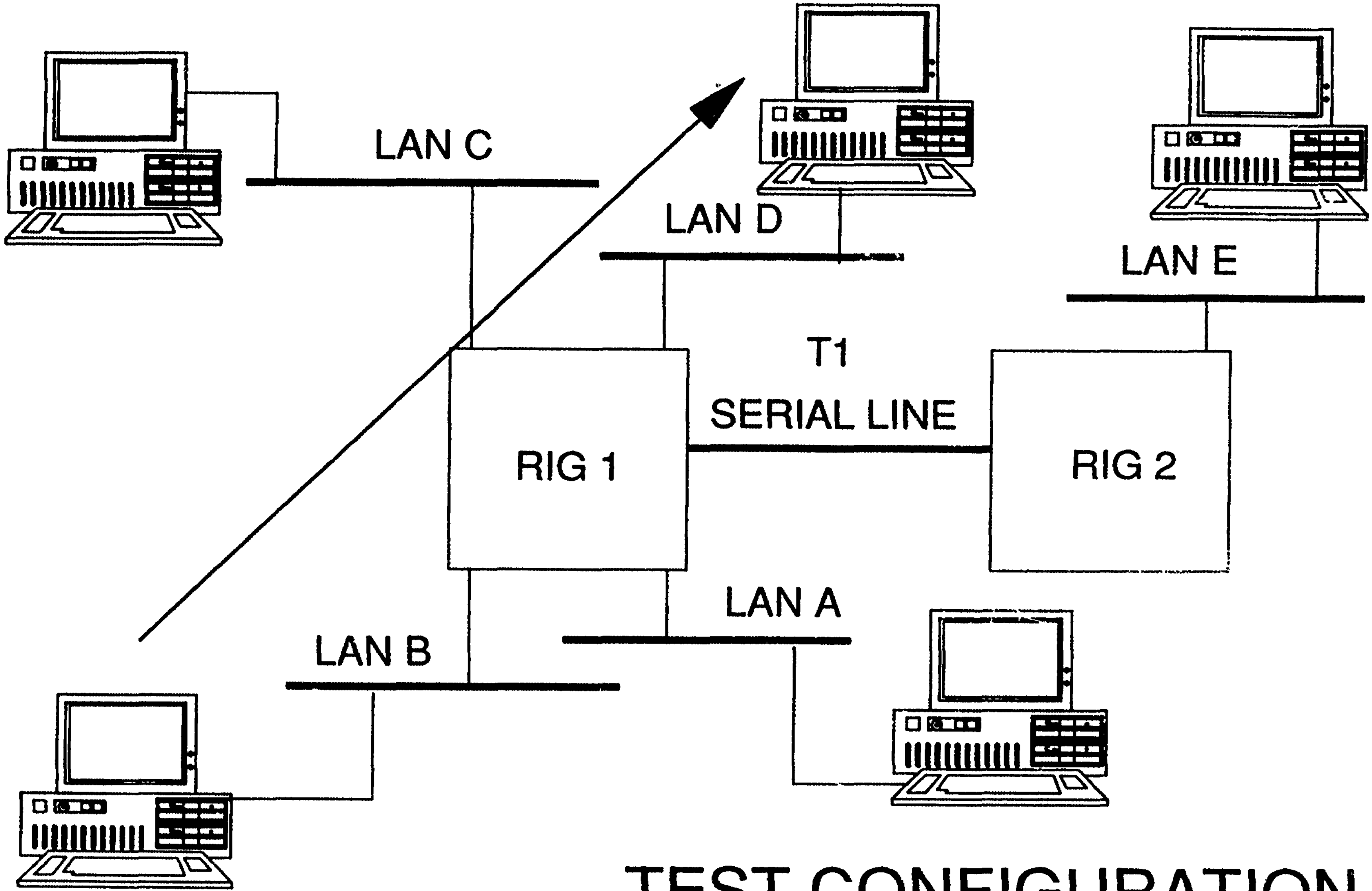
- wordprocessing;
- spreadsheets;
- business graphics;
- database management; and,
- communications.

Along with Symphony, Freelance, a program to create charts and drawings, was used to enhance the graphs and allow for them to be printed out on the laser printer. The graphic results made it much easier to compare CISCO and PROTEON. The reliability and durability of each rig was easily compared when analyzing the graphs (FIGURES 1 - 49).

In order for the graphs to be made, the data needed to be hand typed into the spreadsheet and grouped together, due to the fact there were several runs done on each test. The graphs were then created and transferred to Freelance. The capabilities of Freelance allowed for the graphs to be enhanced and outputted to

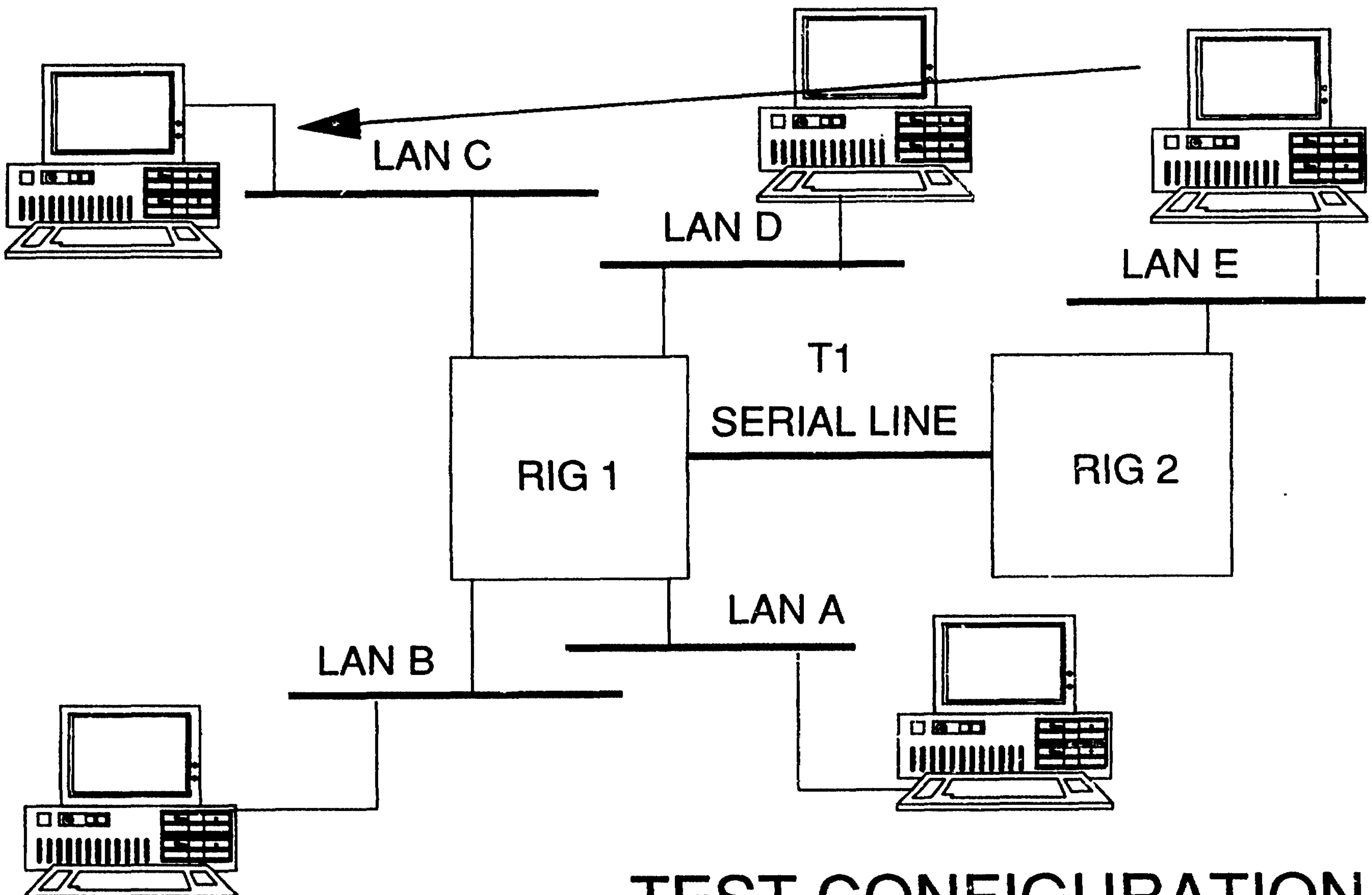
the laser printer. Upon completion, the results could be further studied and conclusions could then be drawn.

Once both assigned projects were completed, I was assured of my career choice. I discovered that engineering combines many fields and each contributes it's own part. Computers are just an example of a device that plays an enormous part in developing chips, boards, programs, and other "engineering tools". Working within the Network Design Lab, enabled me to learn something that is not taught in a textbook. I learned what working in the engineering world is all about and acquired hands-on experience that will be very beneficial in the future. I feel that I learned a great deal of vital information and am confident in the career I have chosen. The people in the Network Design Lab really taught me a lot about engineering and made this summer become a very rewarding and worthwhile experience.



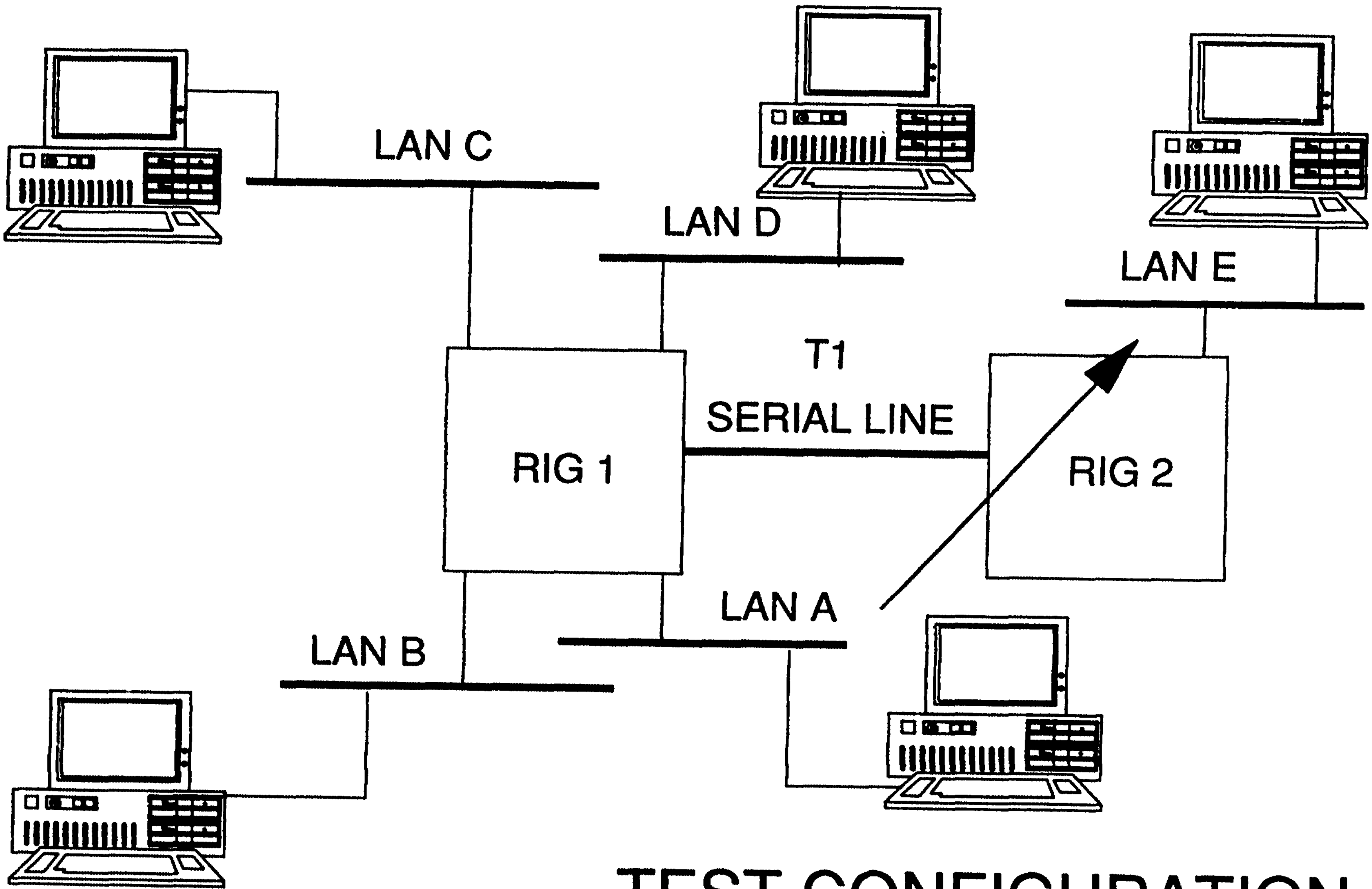
TEST CONFIGURATION

(FIGURE 1)



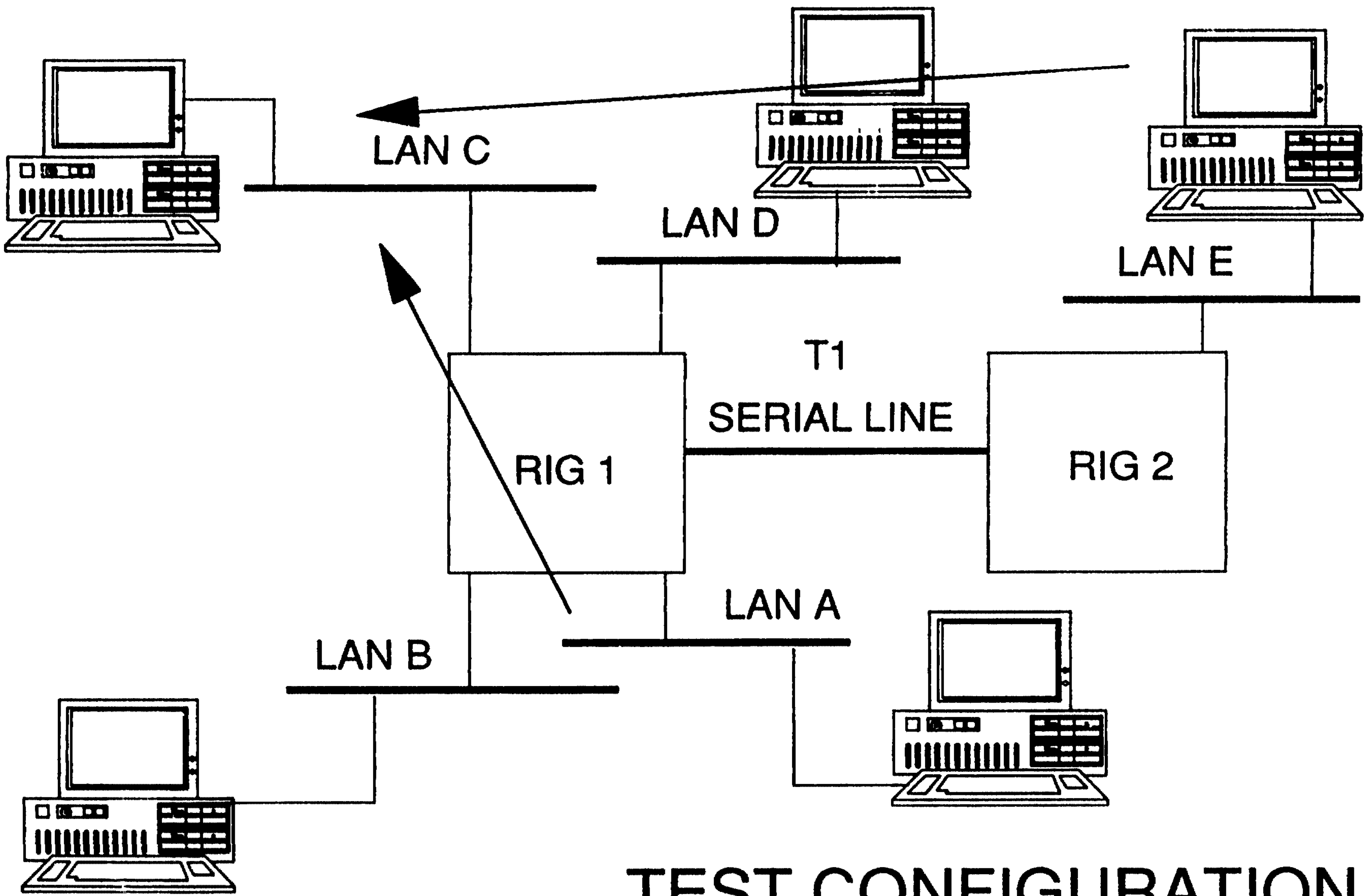
TEST CONFIGURATION

(FIGURE 2)



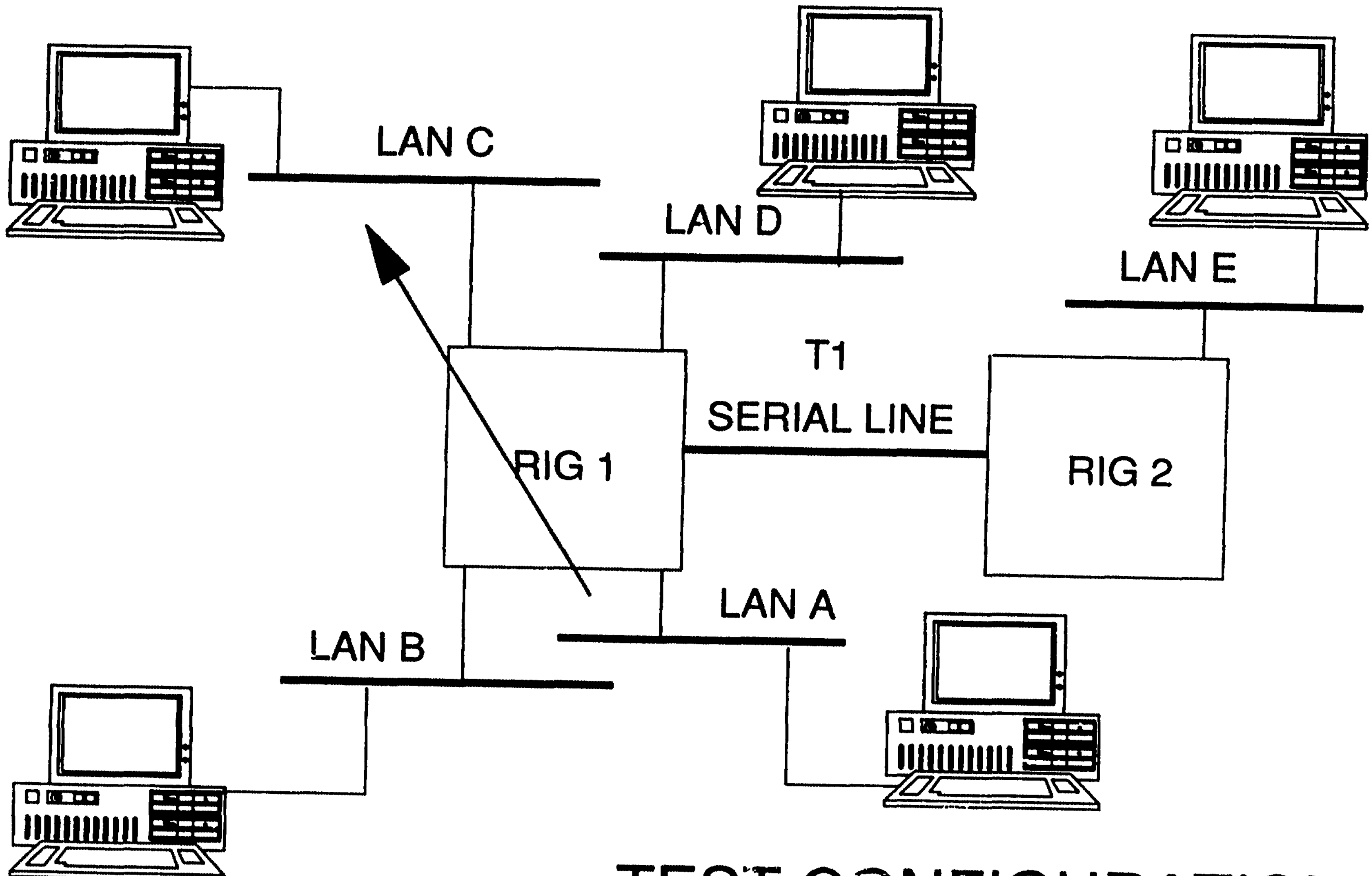
TEST CONFIGURATION

(FIGURE 3)



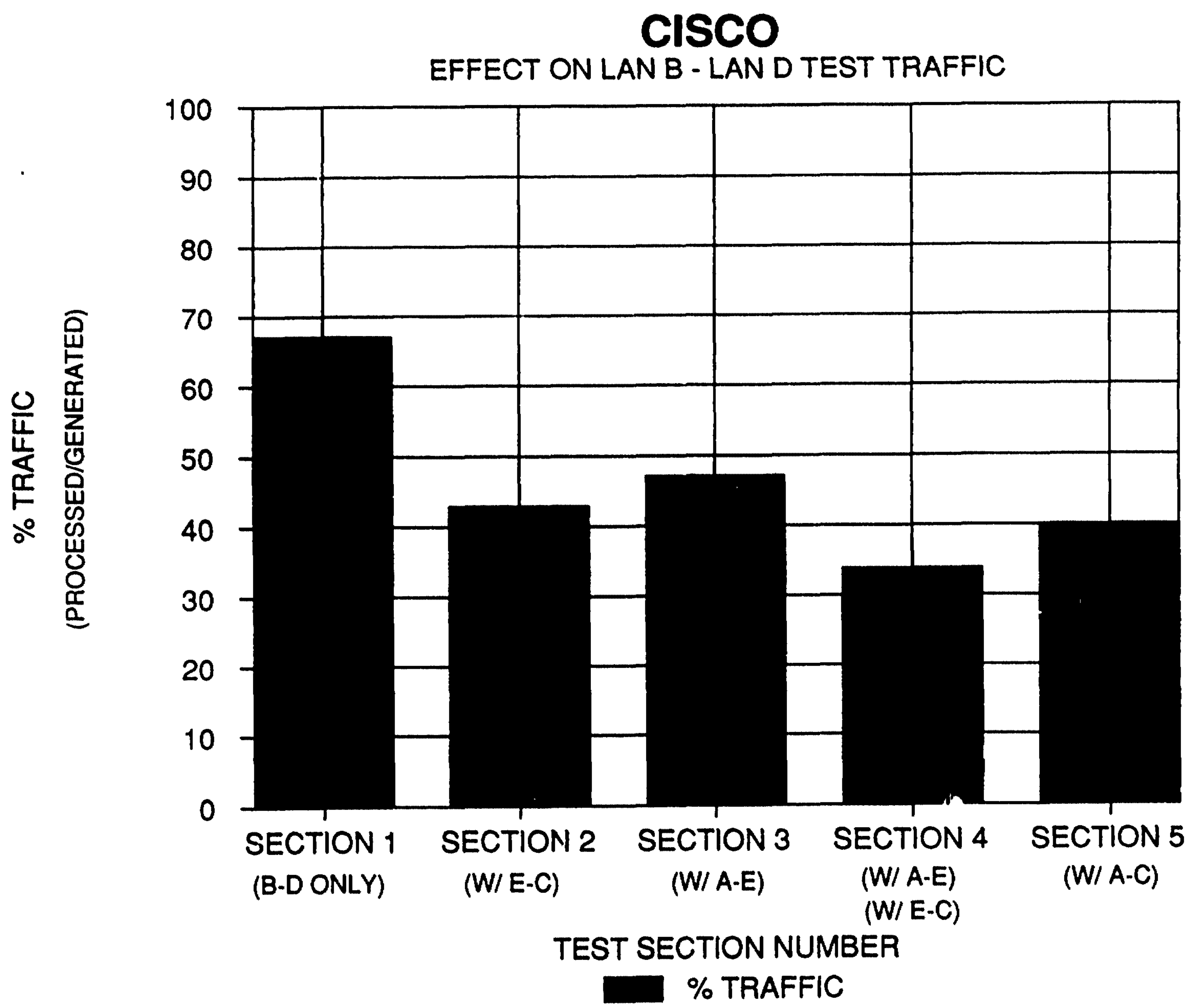
TEST CONFIGURATION

(FIGURE 4)

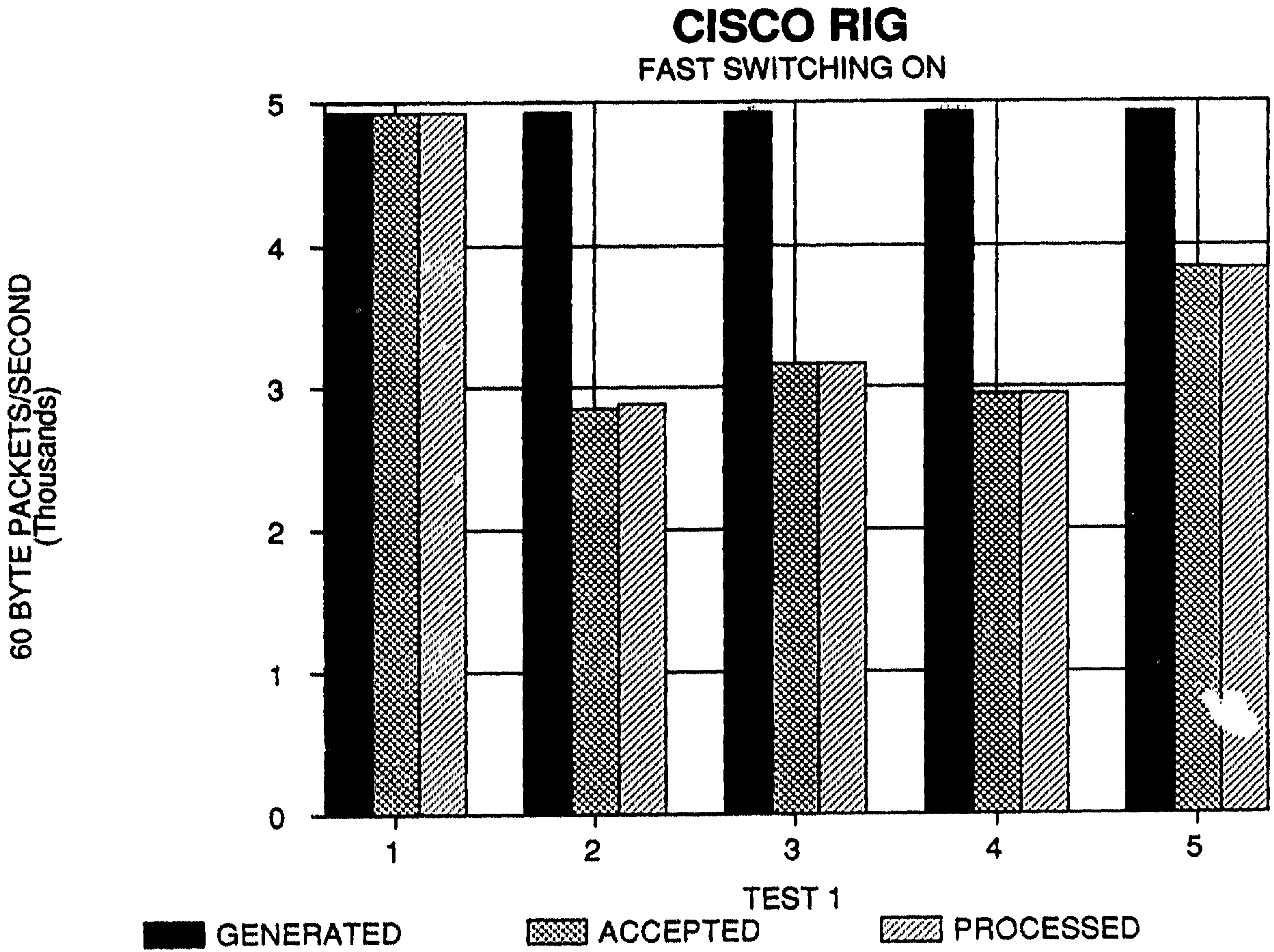


TEST CONFIGURATION

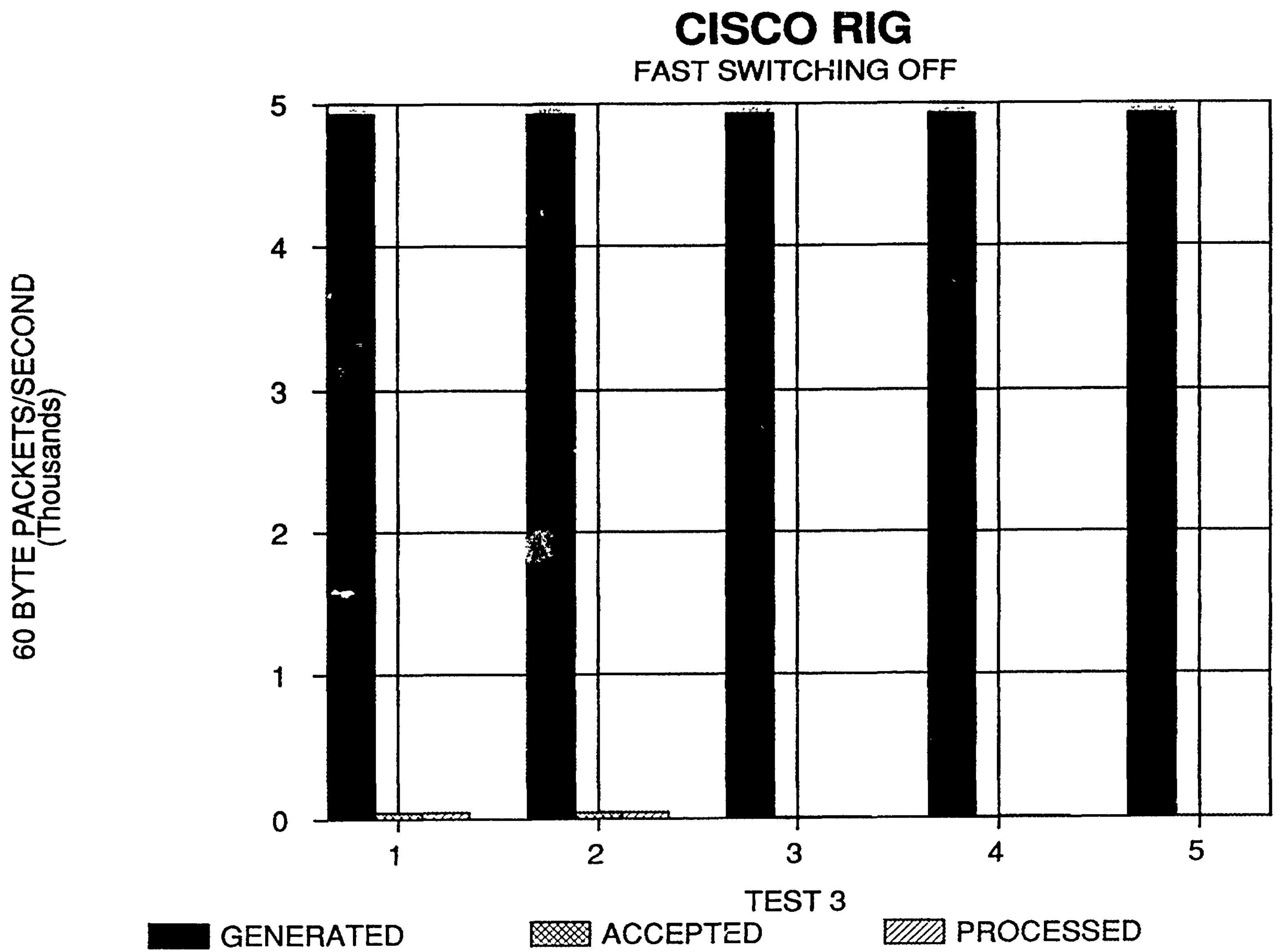
(FIGURE 5)


CISCO
EFFECT ON LAN B - LAN D TEST TRAFFIC
% TRAFFIC
(PROCESSED/GENERATED)
100
90
80
70
60
50
40
30
20
10
0
SECTION 1
(B-D ONLY)
SECTION 2
(W/ E-C)
SECTION 3
(W/ A-E)
SECTION 4
(W/ A-E)
(W/ E-C)
SECTION 5
(W/ A-C)
TEST SECTION NUMBER
% TRAFFIC

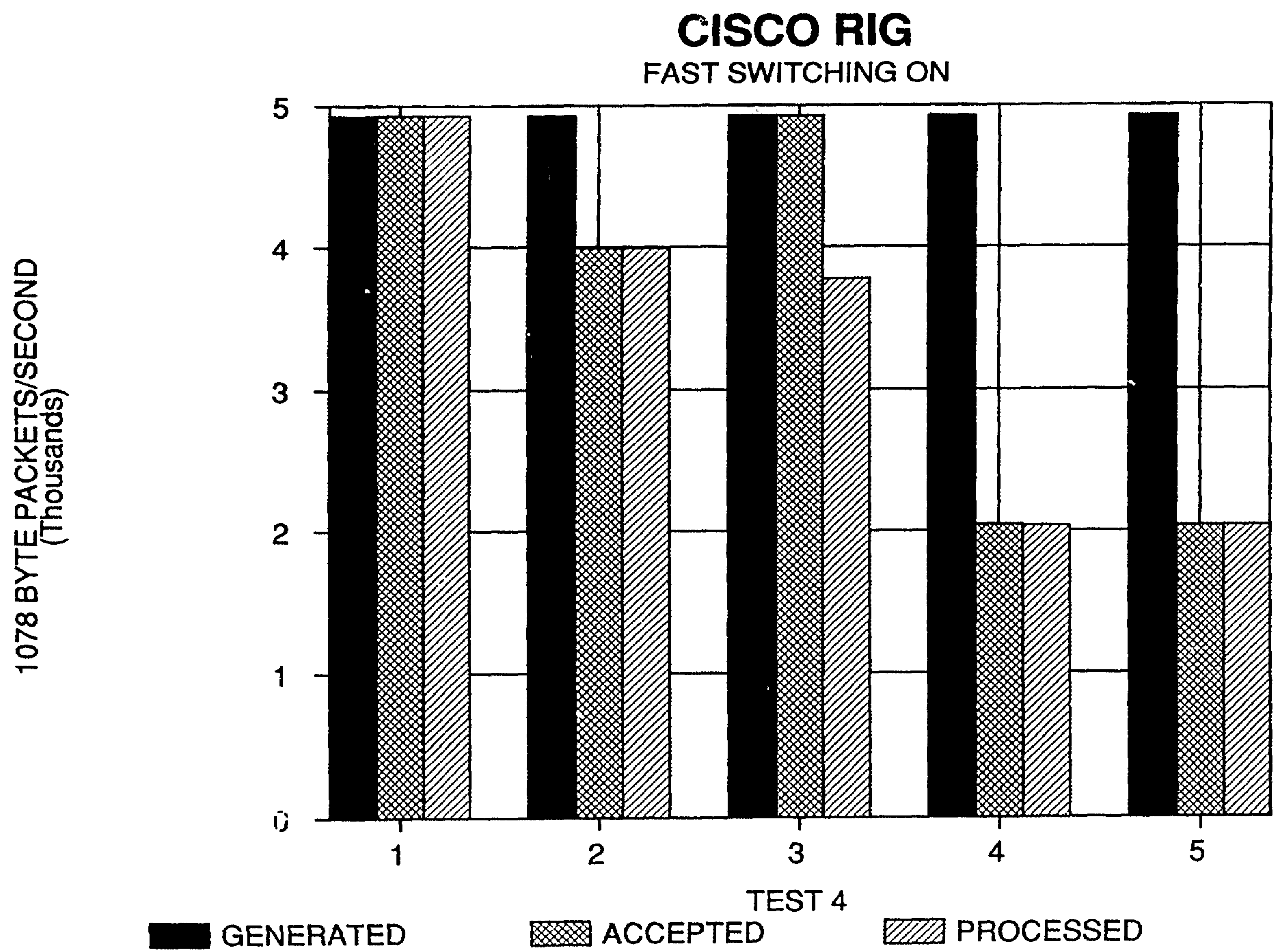
(FIGURE 6)


CISCO RIG
FAST SWITCHING ON
60 BYTE PACKETS/SECOND
(Thousands)
5
4
3
2
1
0
1
2
3
4
5
TEST 1
GENERATED
ACCEPTED
PROCESSED

(FIGURE 7)

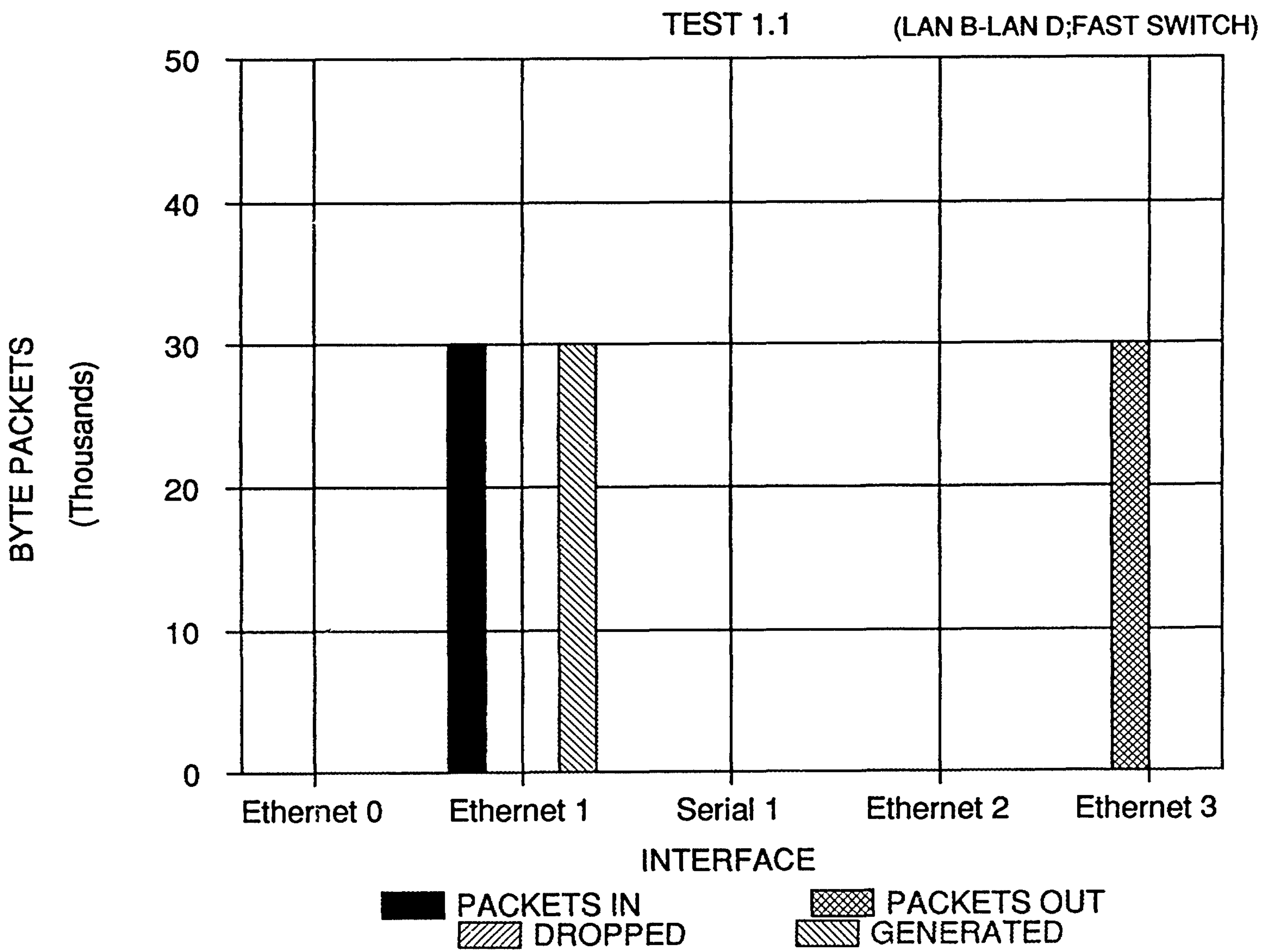

CISCO RIG
FAST SWITCHING OFF
60 BYTE PACKETS/SECOND
(Thousands)
5
4
3
2
1
0
1
2
3
4
5
TEST 3
GENERATED
ACCEPTED
PROCESSED

(FIGURE 8)


CISCO RIG
FAST SWITCHING ON
1078 BYTE PACKETS/SECOND
(Thousands)
5
4
3
2
1
0
1
2
3
4
5
TEST 4
GENERATED
ACCEPTED
PROCESSED

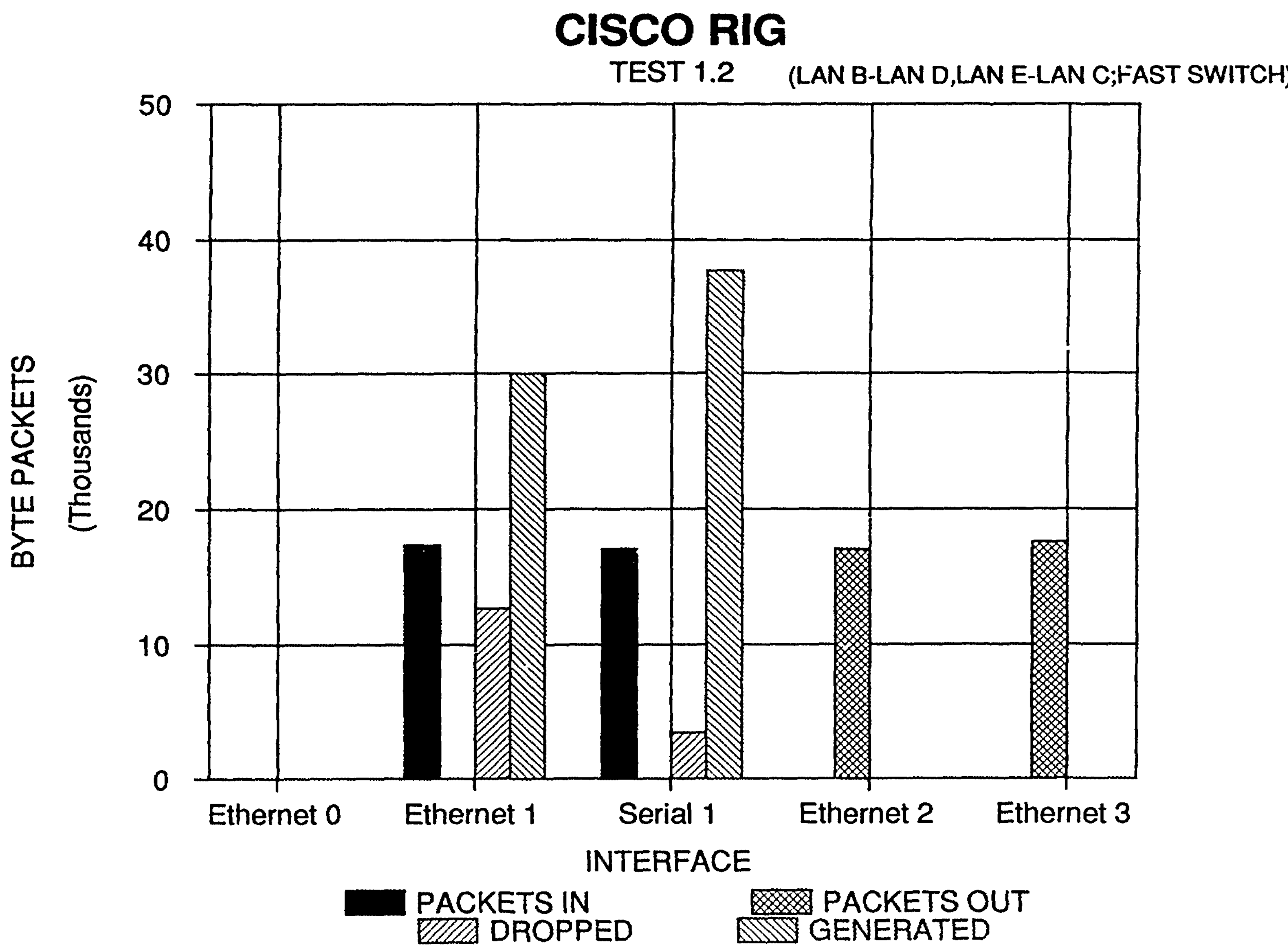
(FIGURE 9)

CISCO RIG



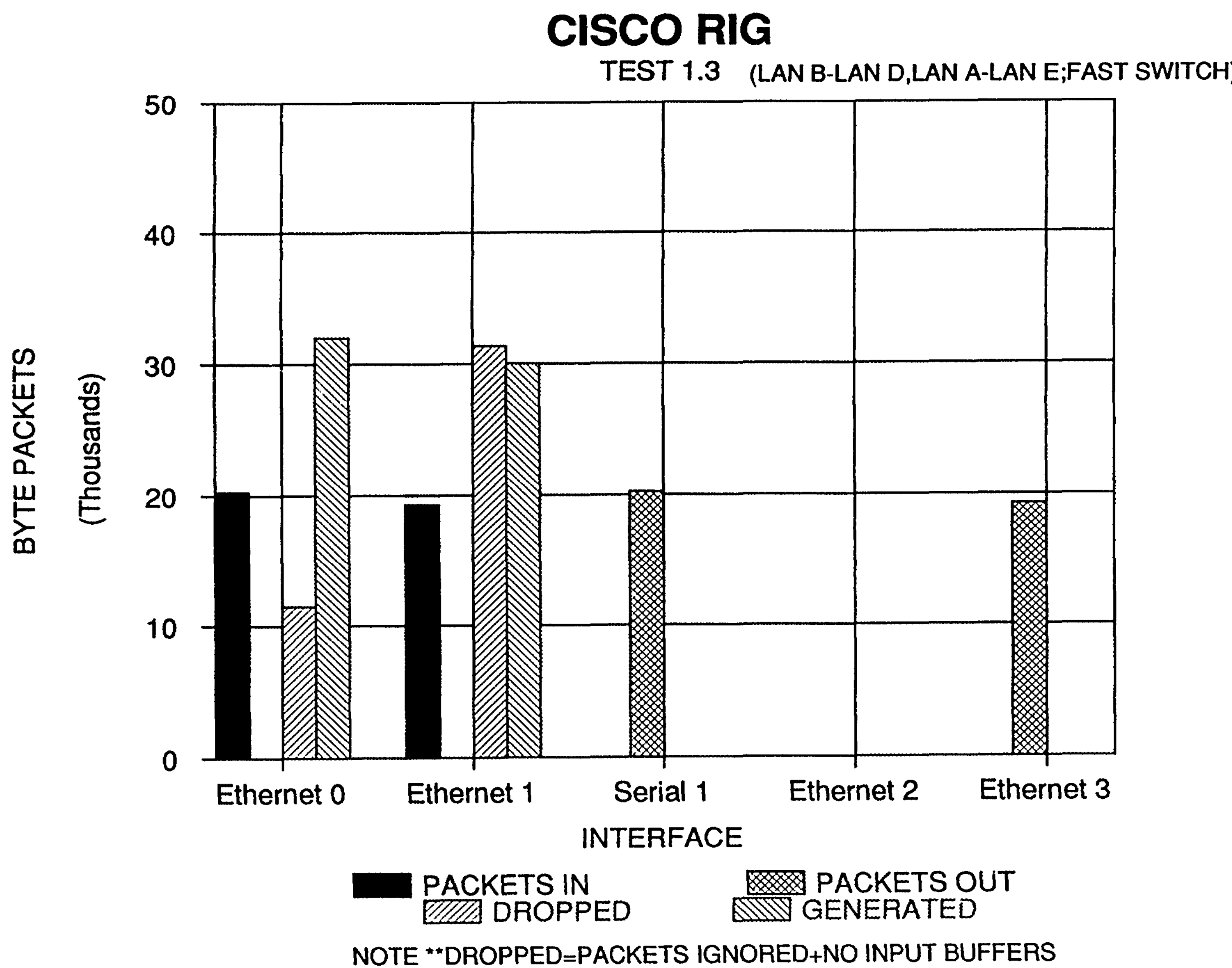
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 10)

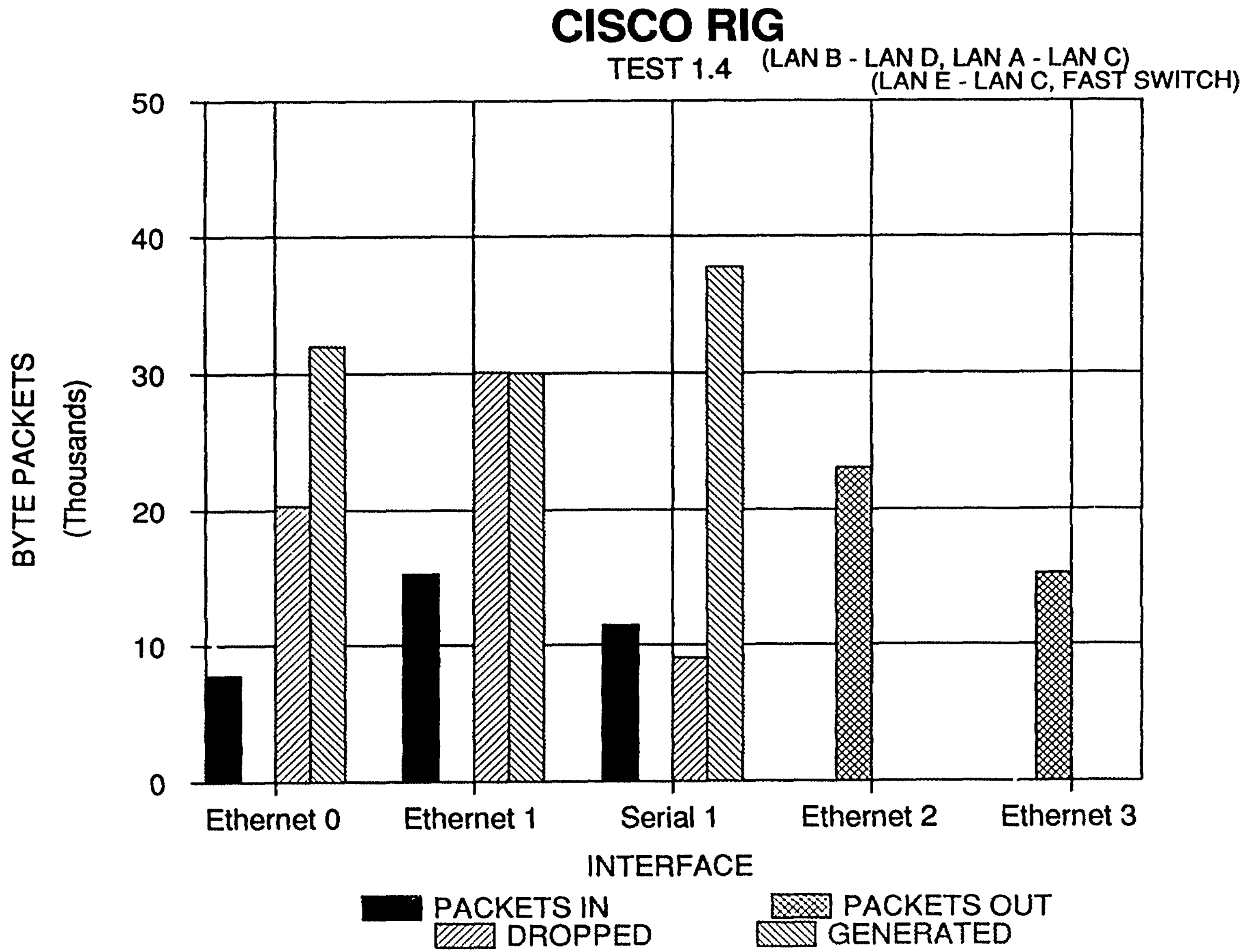


NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 11)

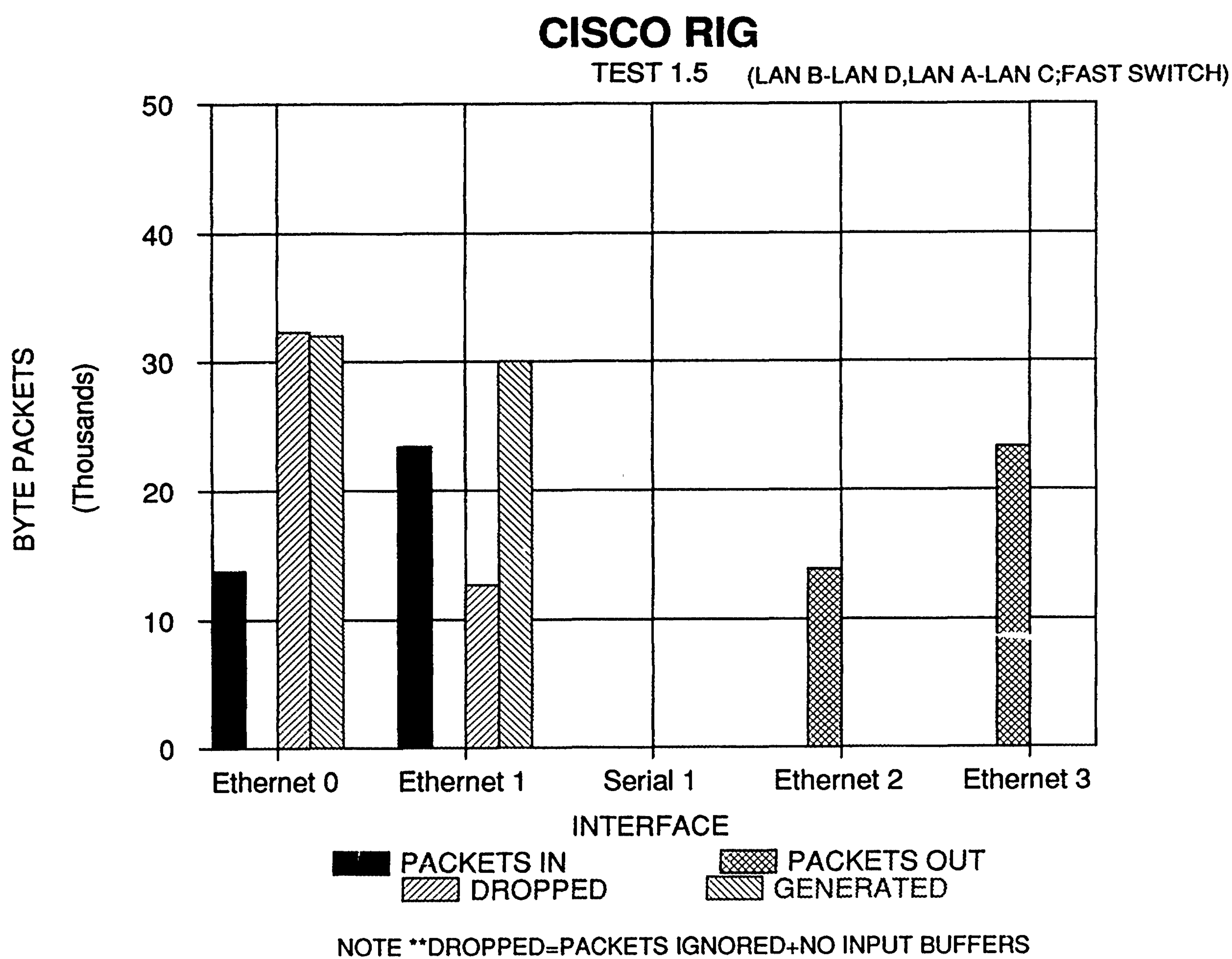

CISCO RIG
TEST 1.3 (LAN B-LAN D,LAN A-LAN E;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 12)

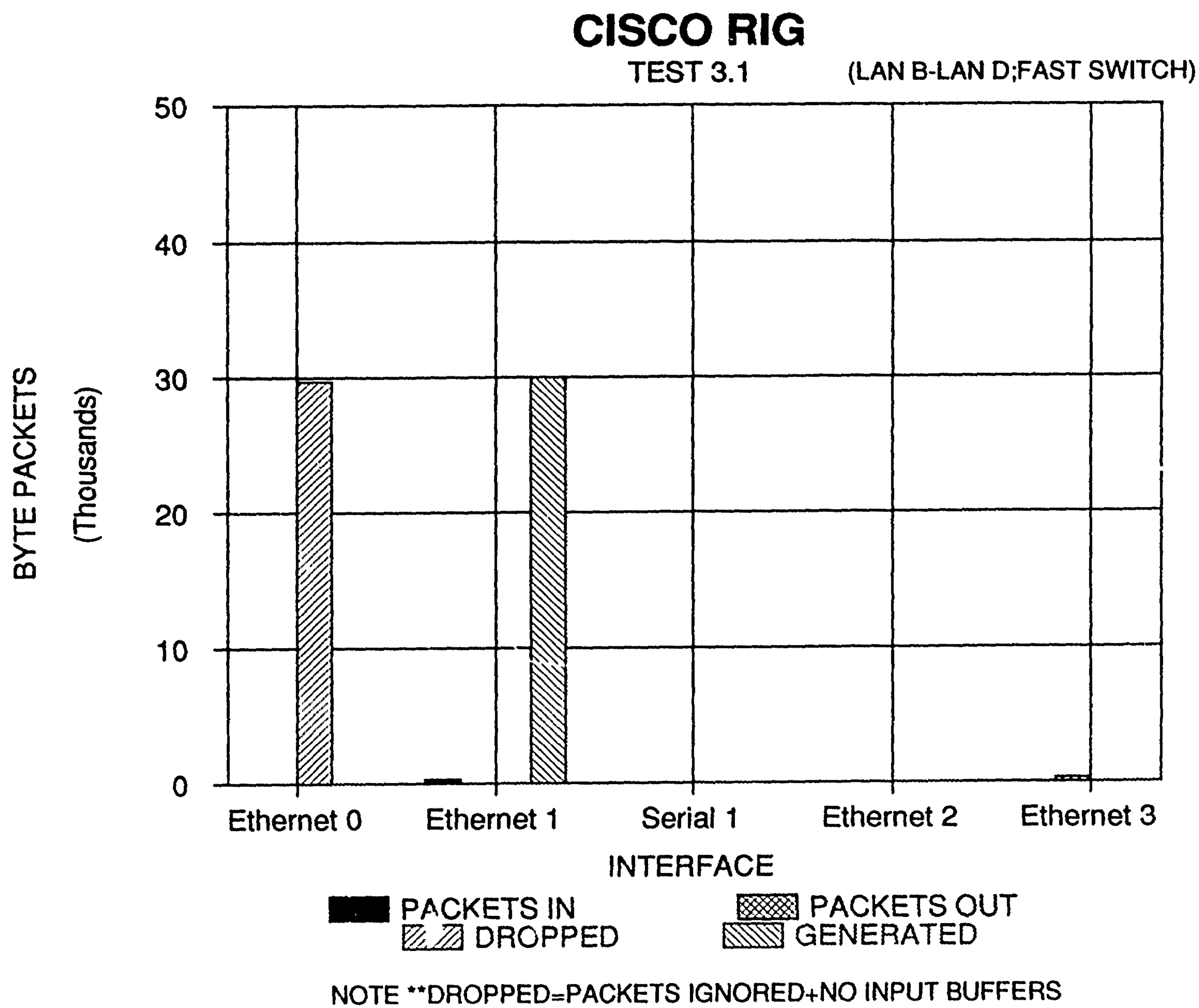


NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

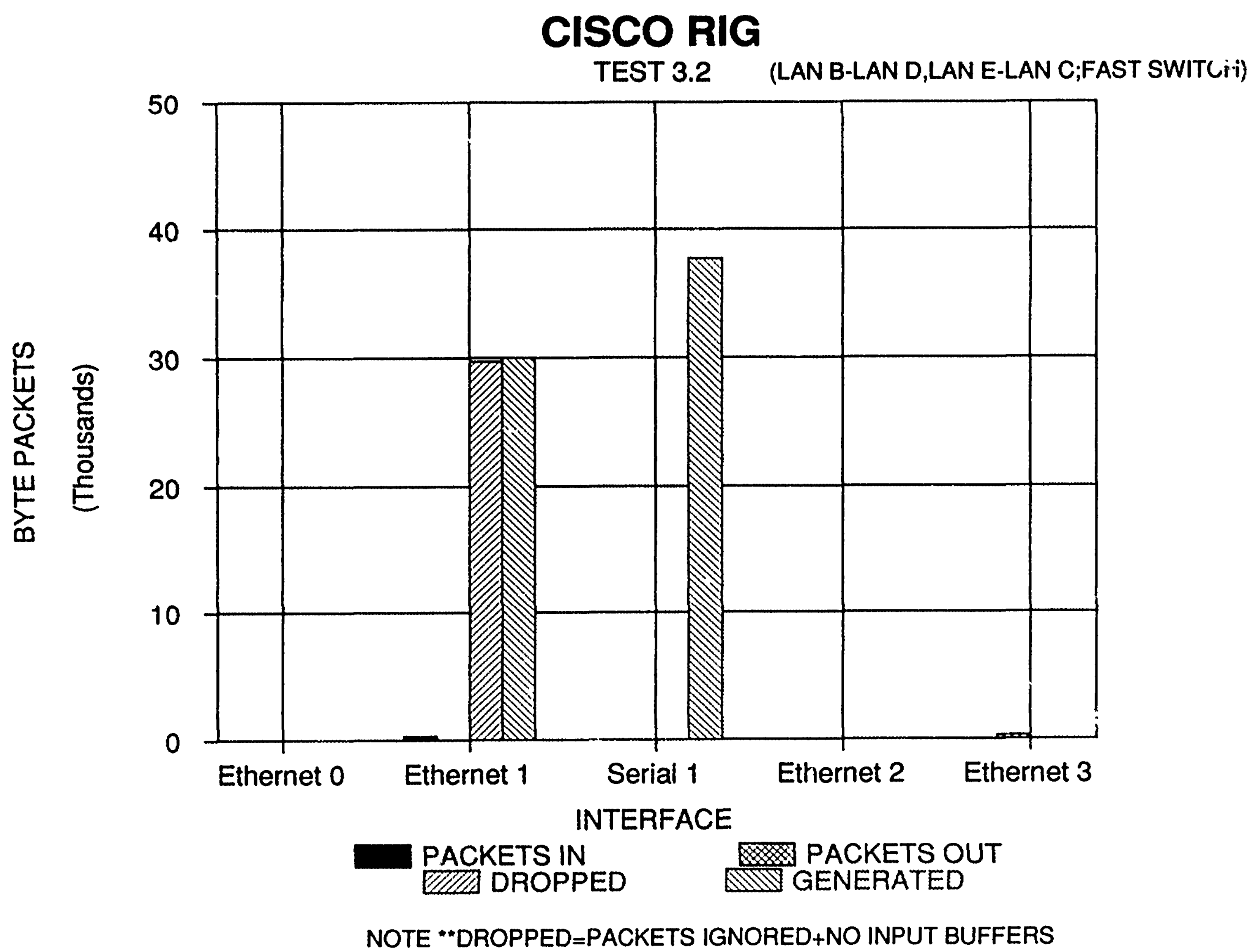
(FIGURE 13)


CISCO RIG
TEST 1.5
(LAN B-LAN D,LAN A-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 14)

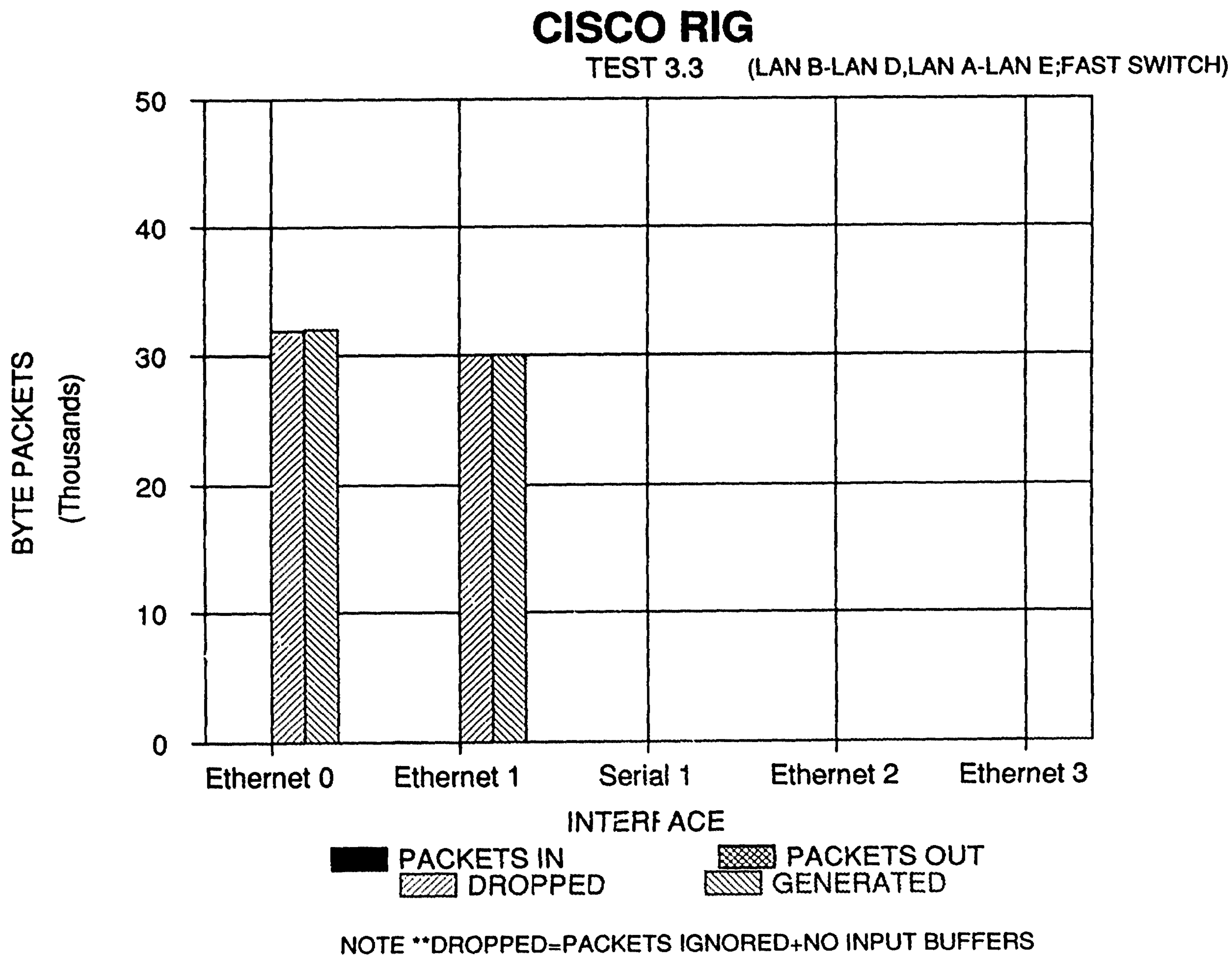

CISCO RIG
TEST 3.1
(LAN B-LAN D;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 15)

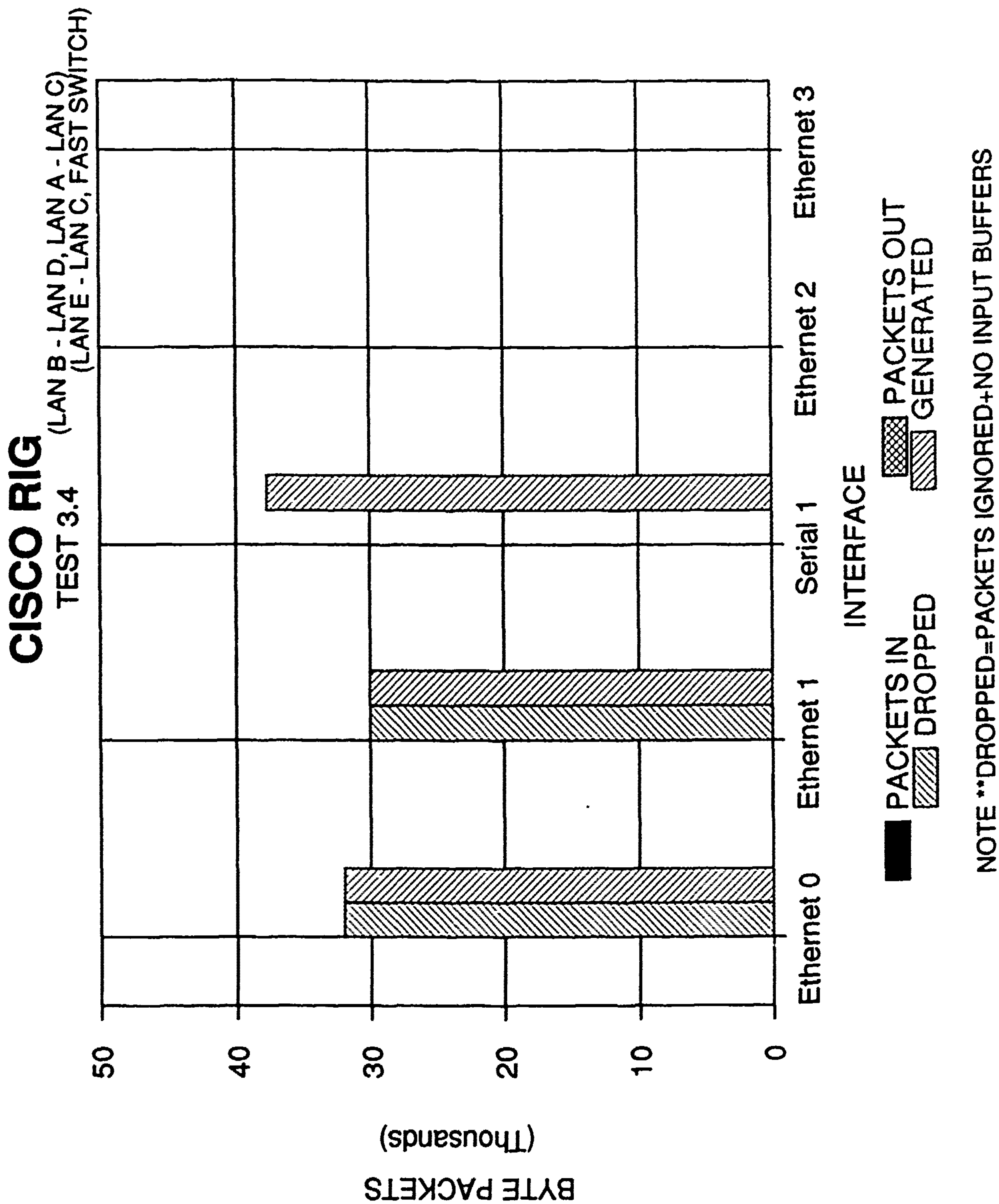


CISCO RIG
TEST 3.2
(LAN B-LAN D,LAN E-LAN C;FAST SWITCH)
50
40
30
20
10
0
BYTE PACKETS
(Thousands)
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

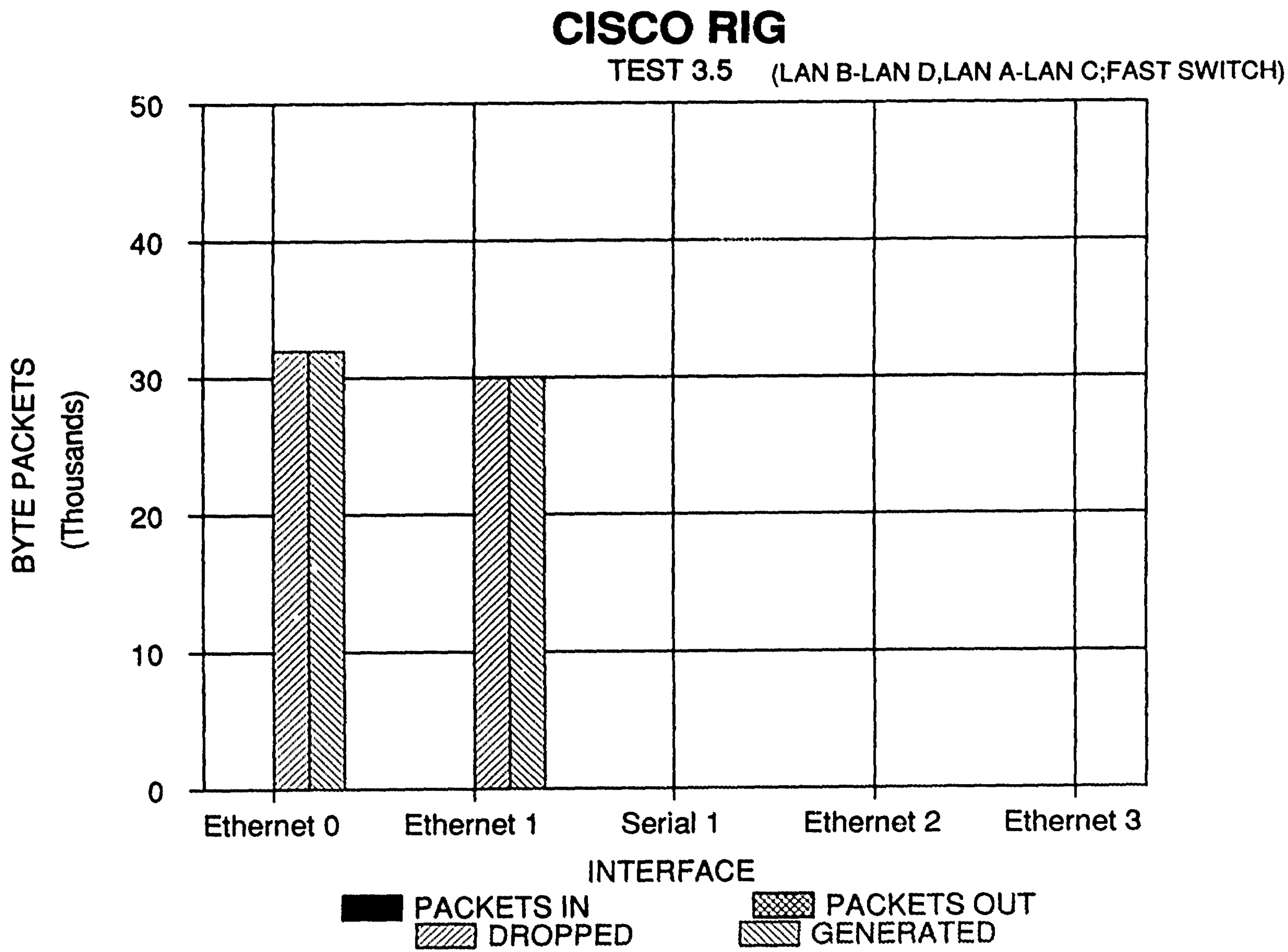
(FIGURE 16)


CISCO RIG
TEST 3.3 (LAN B-LAN D,LAN A-LAN E;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 17)

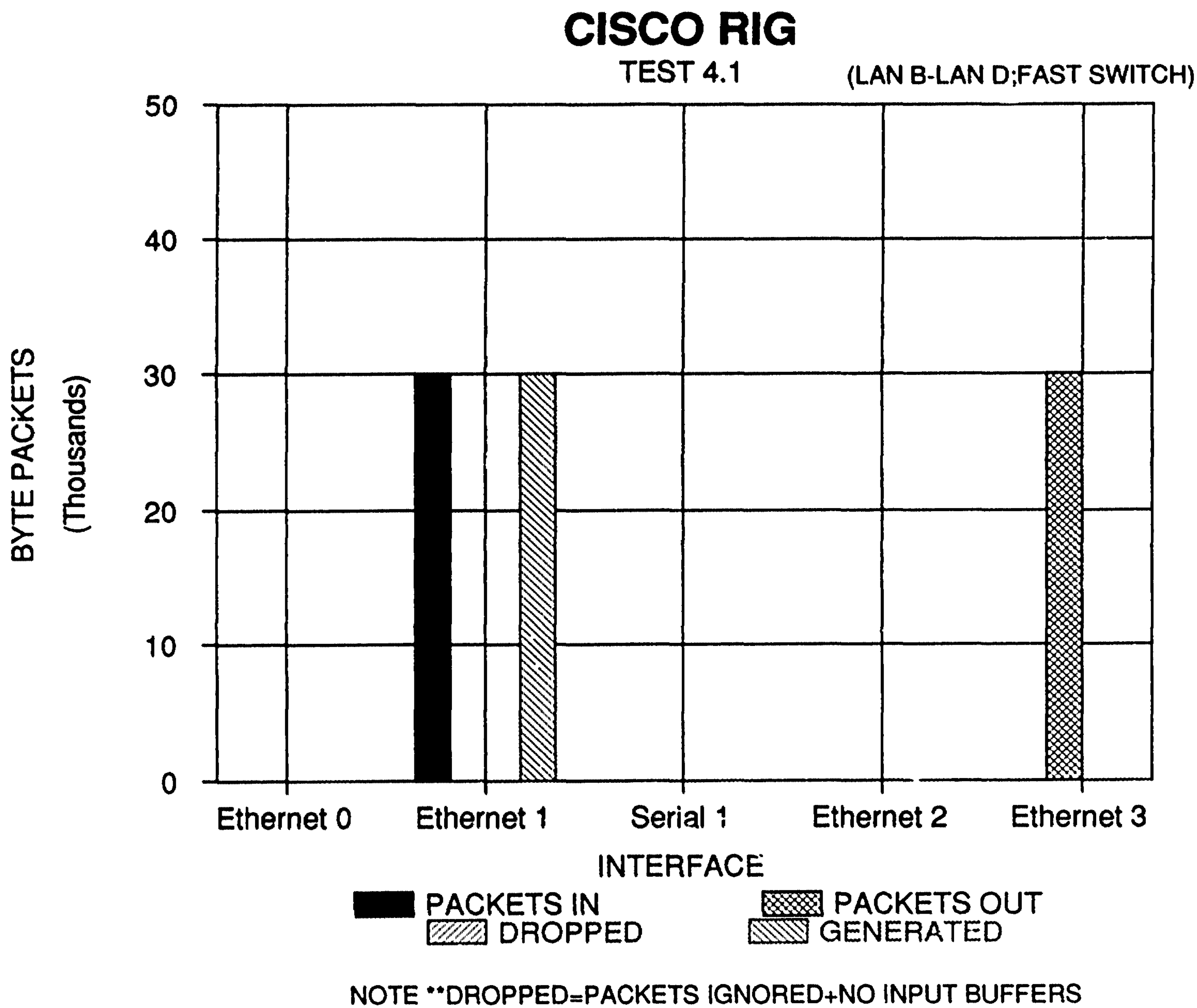

CISCO RIG
TEST 3.4
(LAN B - LAN D, LAN A - LAN C)
(LAN E - LAN C, FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 18)



NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

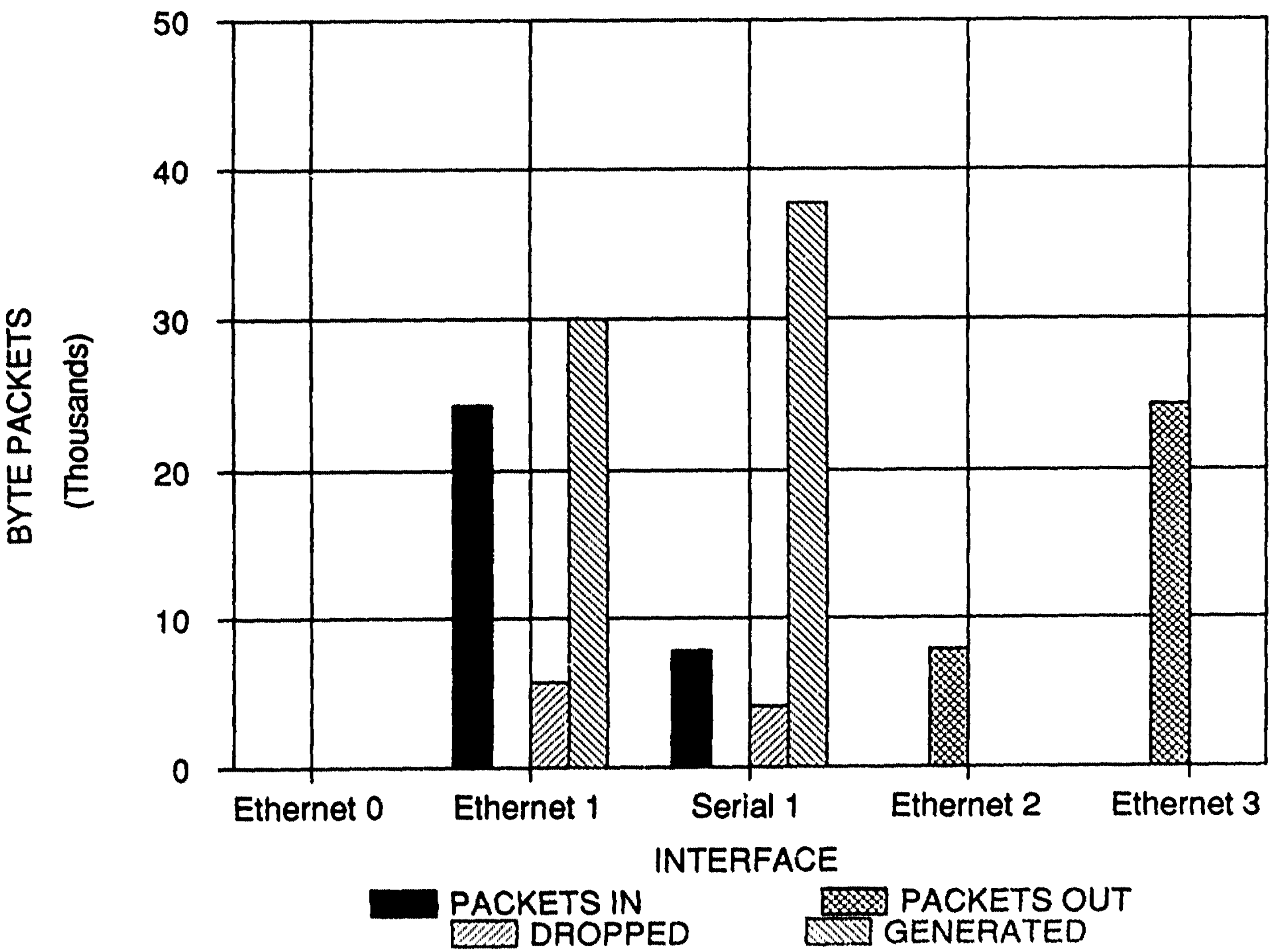
(FIGURE 19)


CISCO RIG
TEST 4.1
(LAN B-LAN D;FAST SWITCH)
50
40
30
20
10
0
BYTE PACKETS
(Thousands)
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 20)

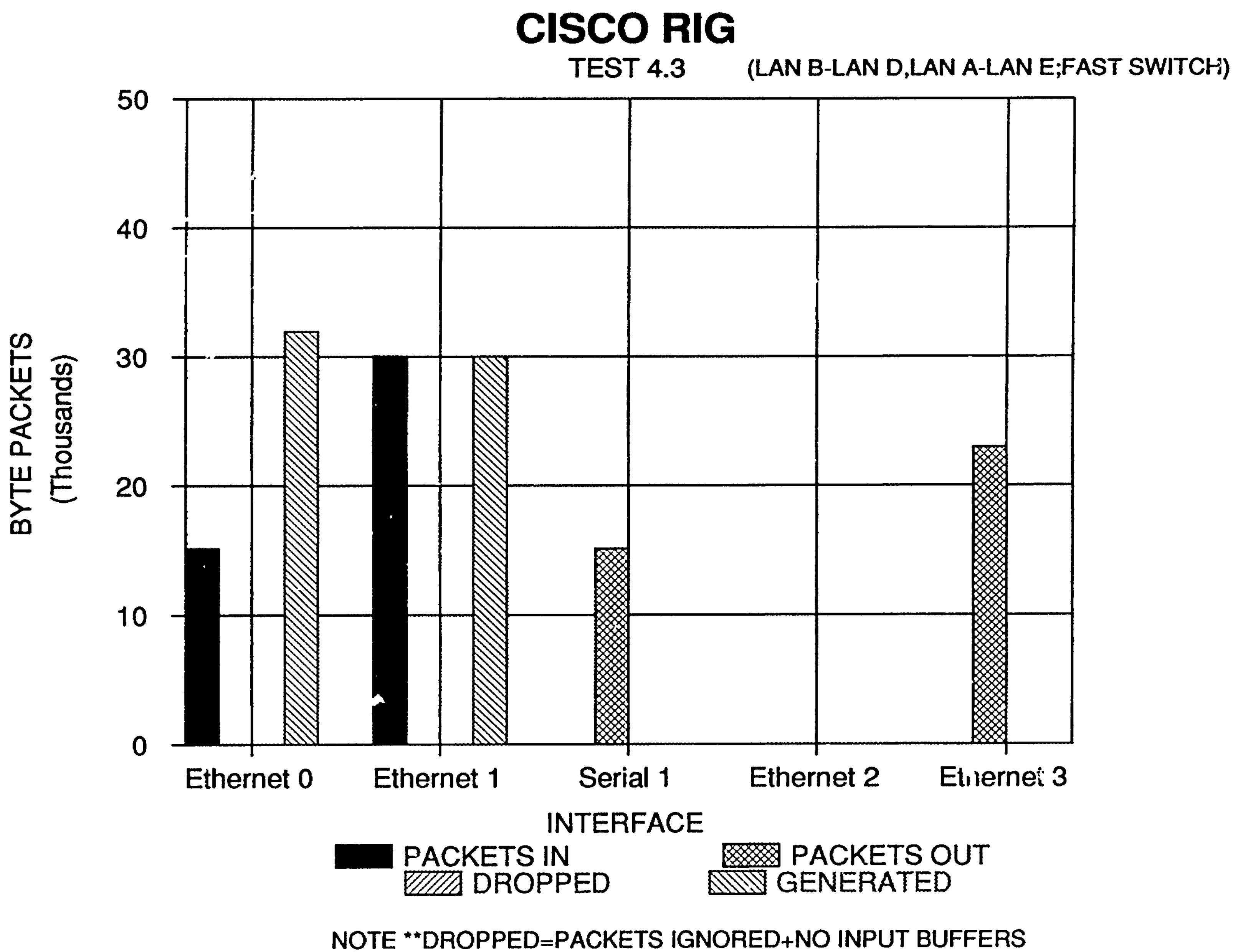
CISCO RIG

TEST 4.2 (LAN B-LAN D,LAN E-LAN C;FAST SWITCH)



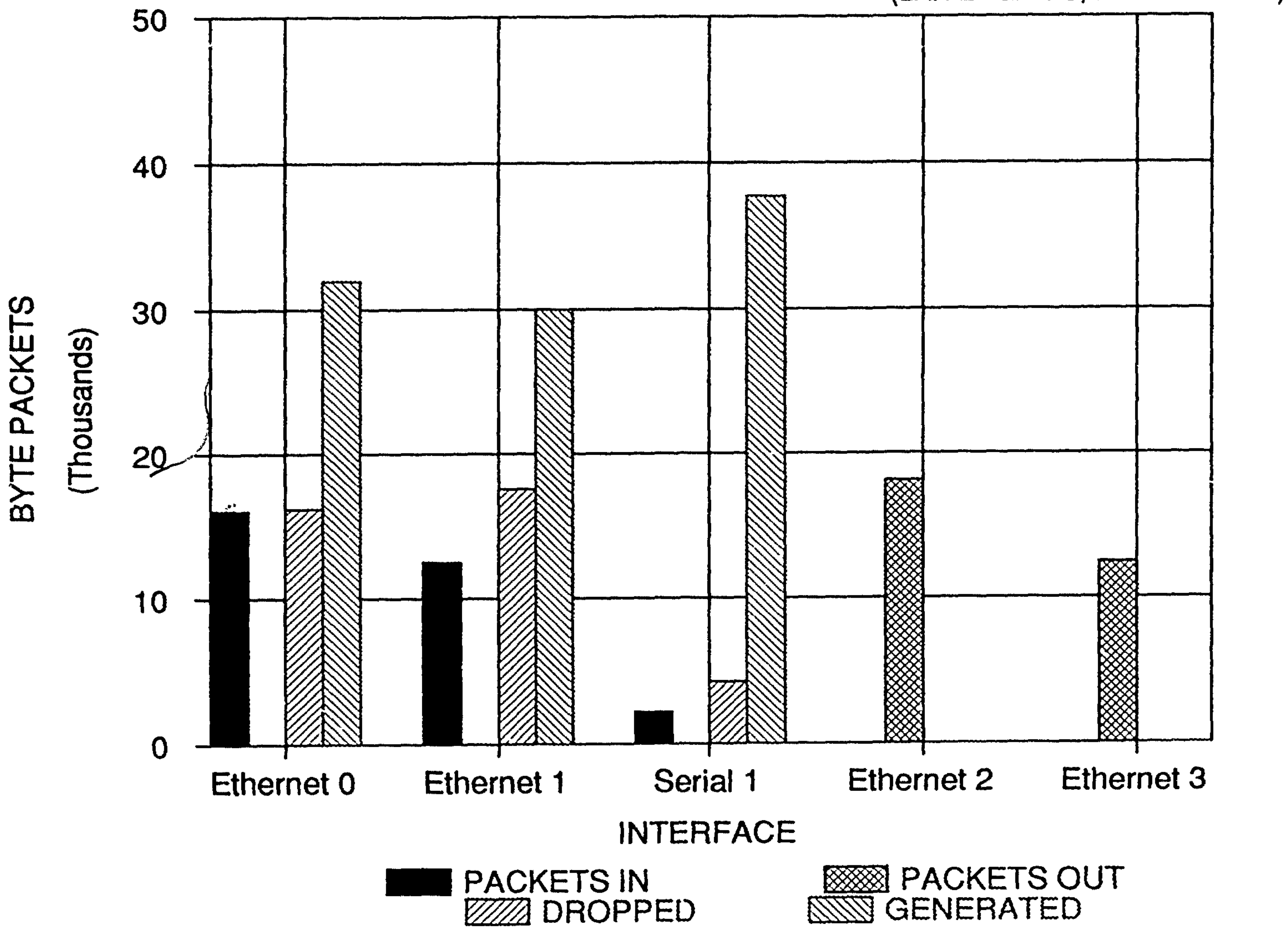
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 21)


CISCO RIG
TEST 4.3
(LAN B-LAN D,LAN A-LAN E;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Ethernet 0
Ethernet 1
Serial 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
DROPPED
PACKETS OUT
GENERATED
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

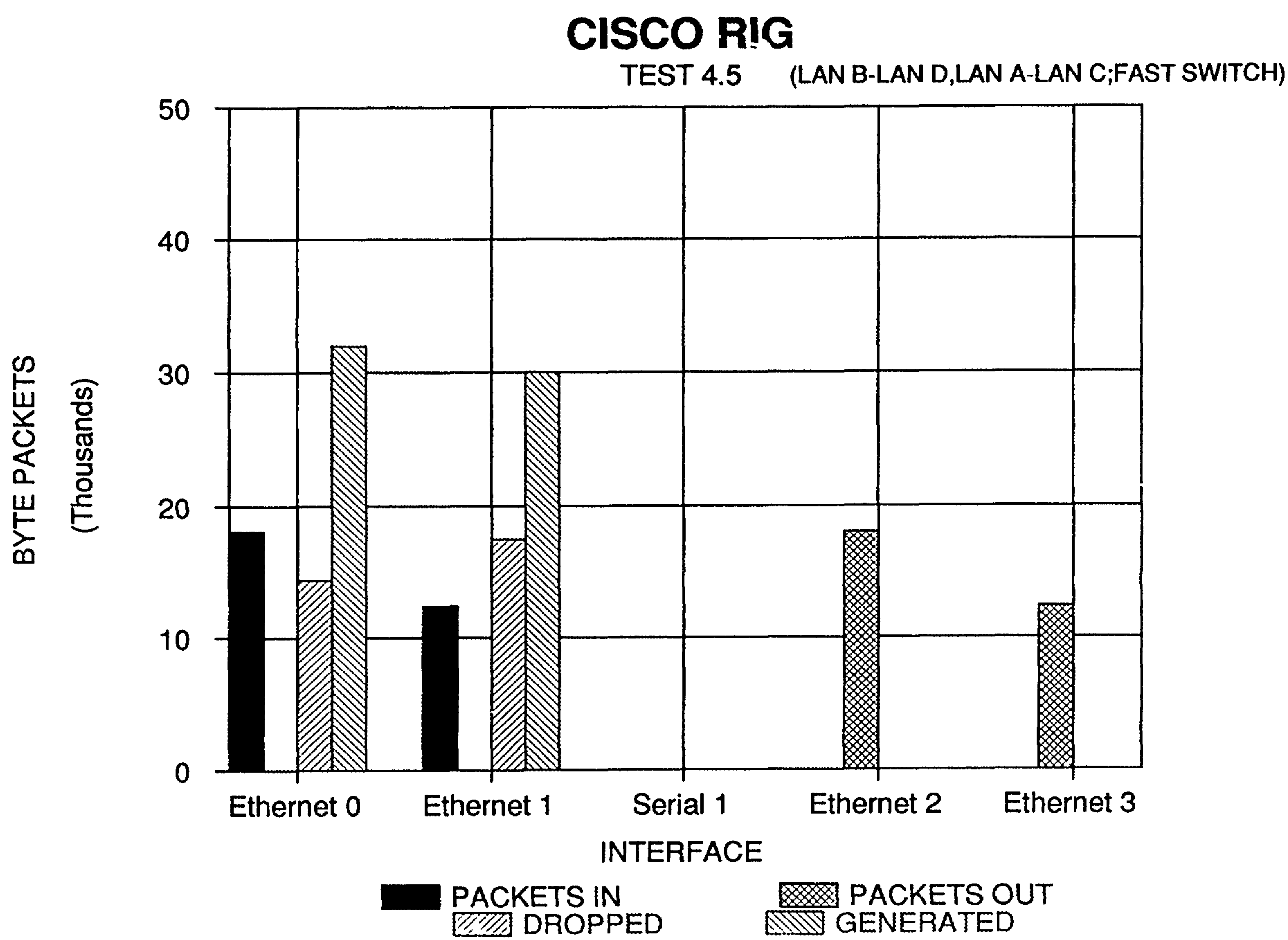
(FIGURE 22)

CISCO RIG
TEST 4.4 (LAN B - LAN D, LAN A - LAN C) (LAN E - LAN C, FAST SWITCH)



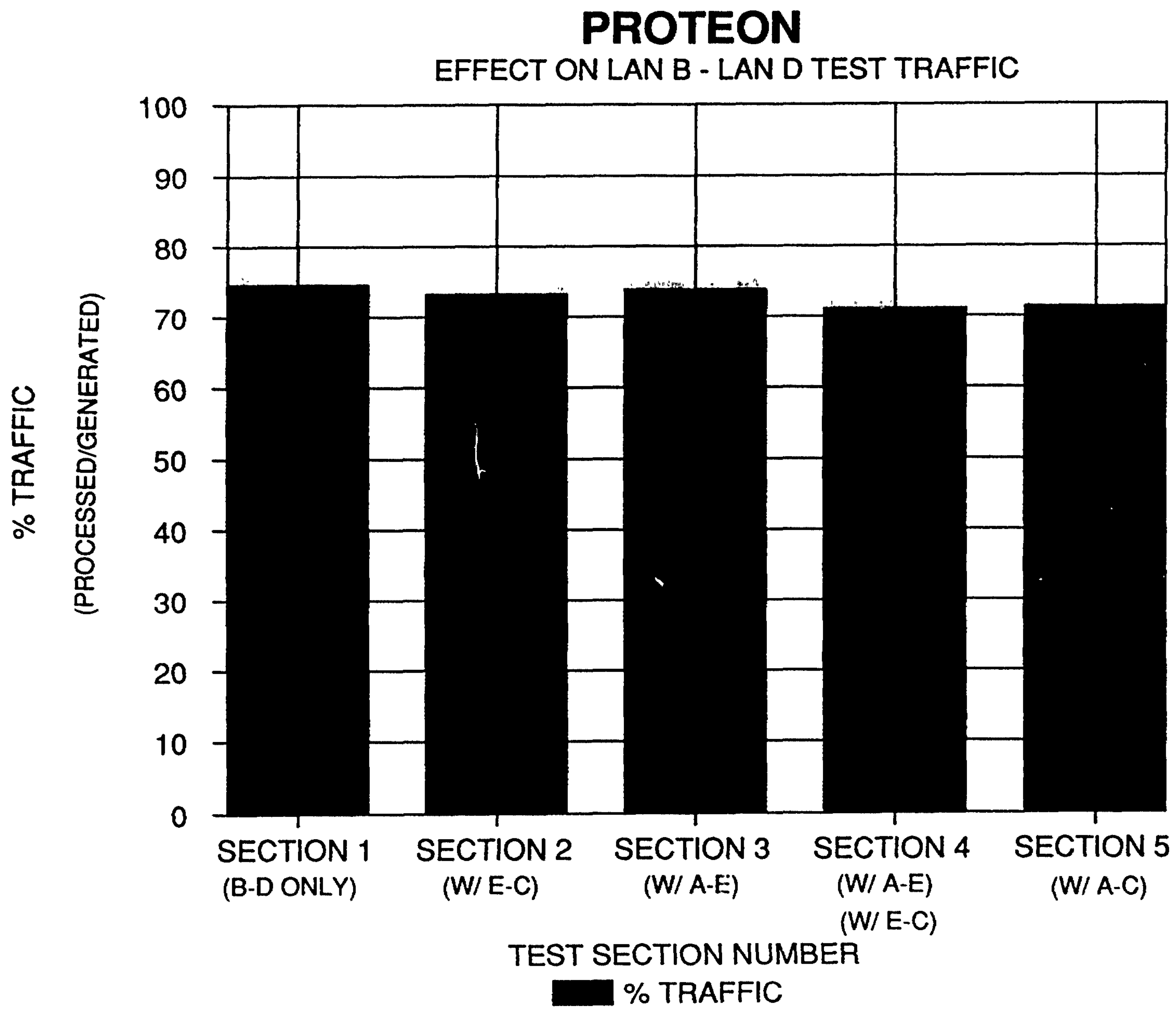
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 23)



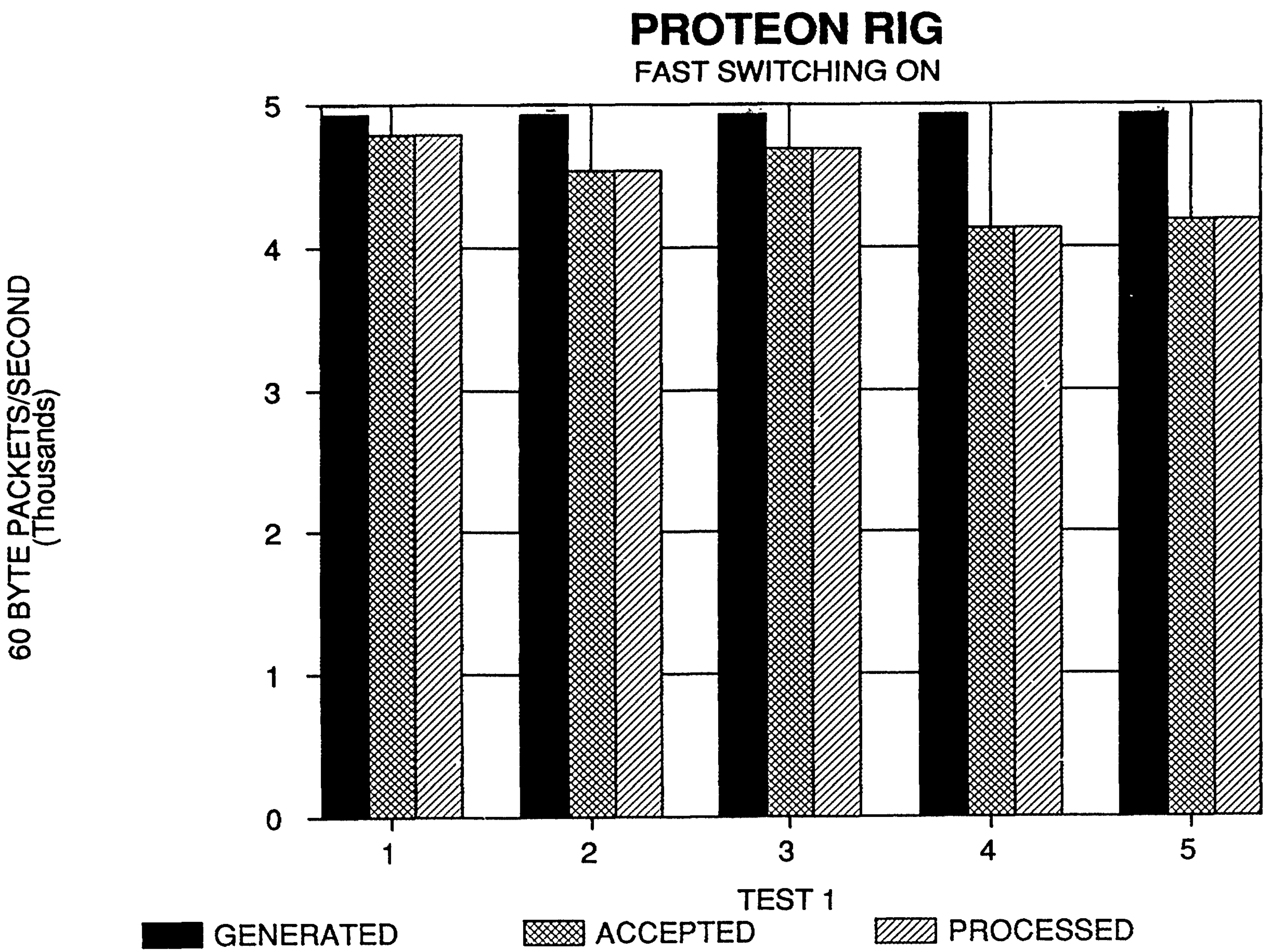
NOTE **DROPPED=PACKETS IGNORED+NO INPUT BUFFERS

(FIGURE 24)

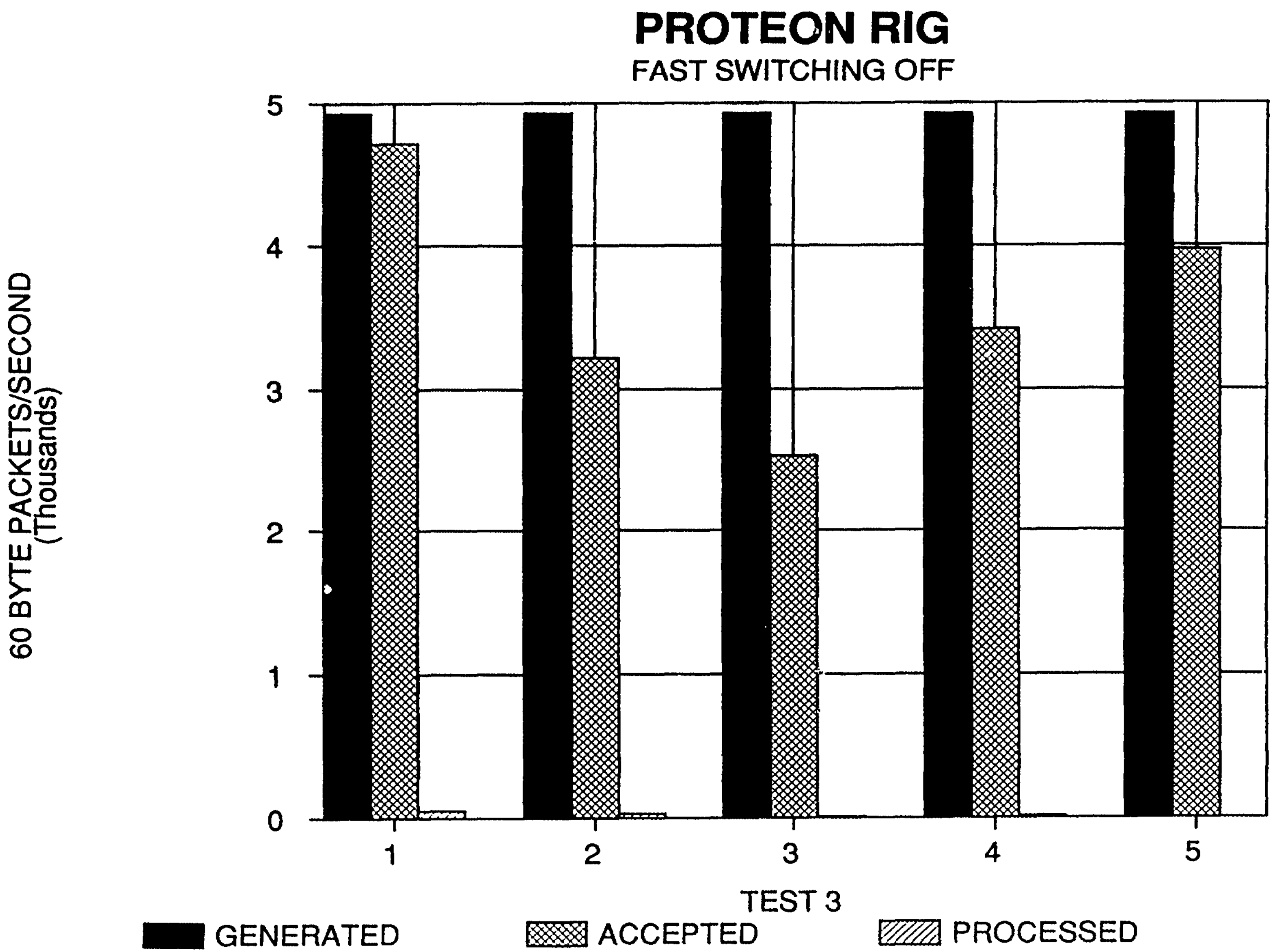


PROTEON
EFFECT ON LAN B - LAN D TEST TRAFFIC
100
90
80
70
60
50
40
30
20
10
0
% TRAFFIC
(PROCESSED/GENERATED)
SECTION 1
(B-D ONLY)
SECTION 2
(W/ E-C)
SECTION 3
(W/ A-E)
SECTION 4
(W/ A-E)
(W/ E-C)
SECTION 5
(W/ A-C)
TEST SECTION NUMBER
% TRAFFIC

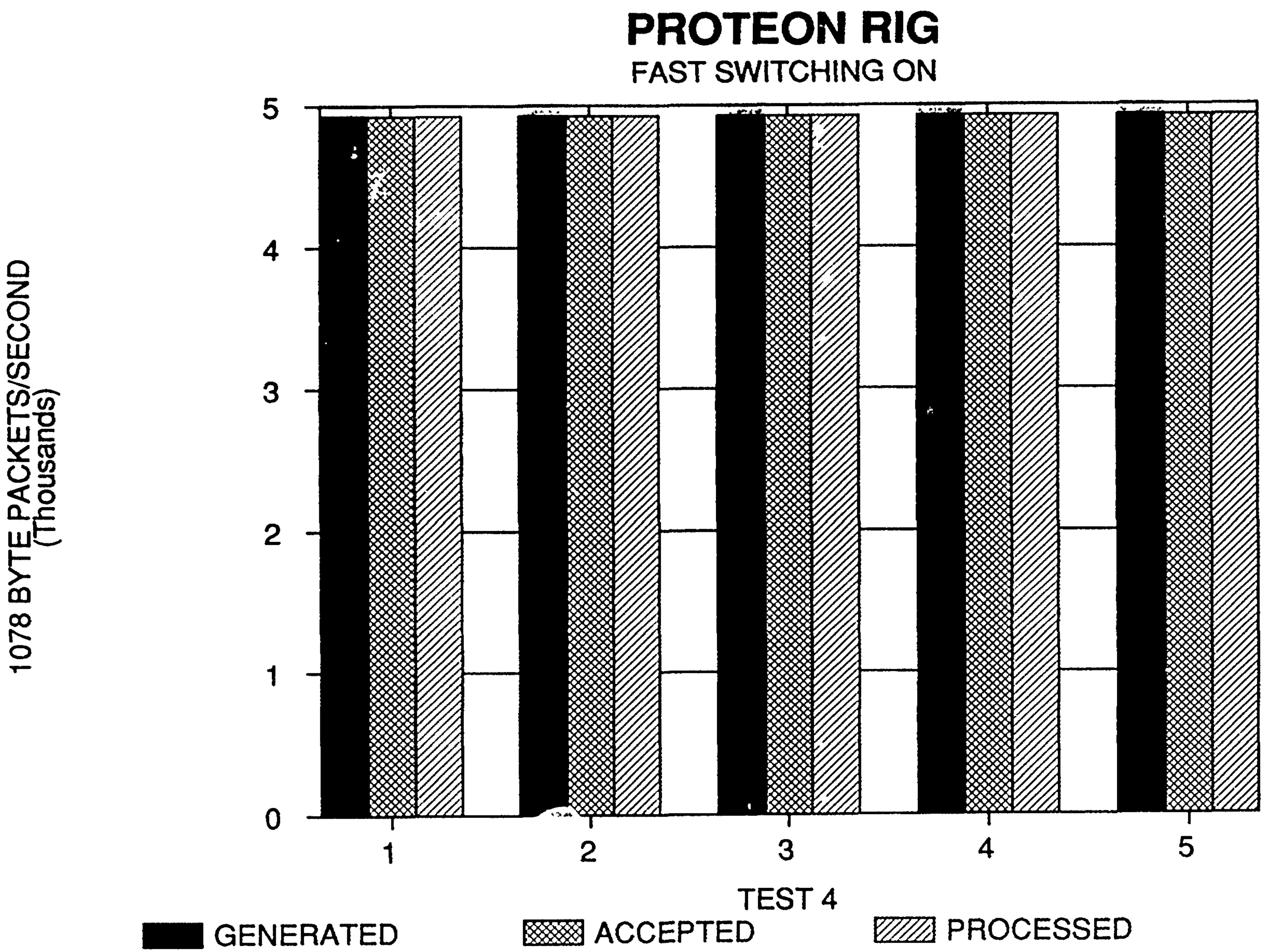
(FIGURE 25)


PROTEON RIG
FAST SWITCHING ON
60 BYTE PACKETS/SECOND
(Thousands)
5
4
3
2
1
0
1
2
3
4
5
TEST 1
GENERATED
ACCEPTED
PROCESSED

(FIGURE 26)

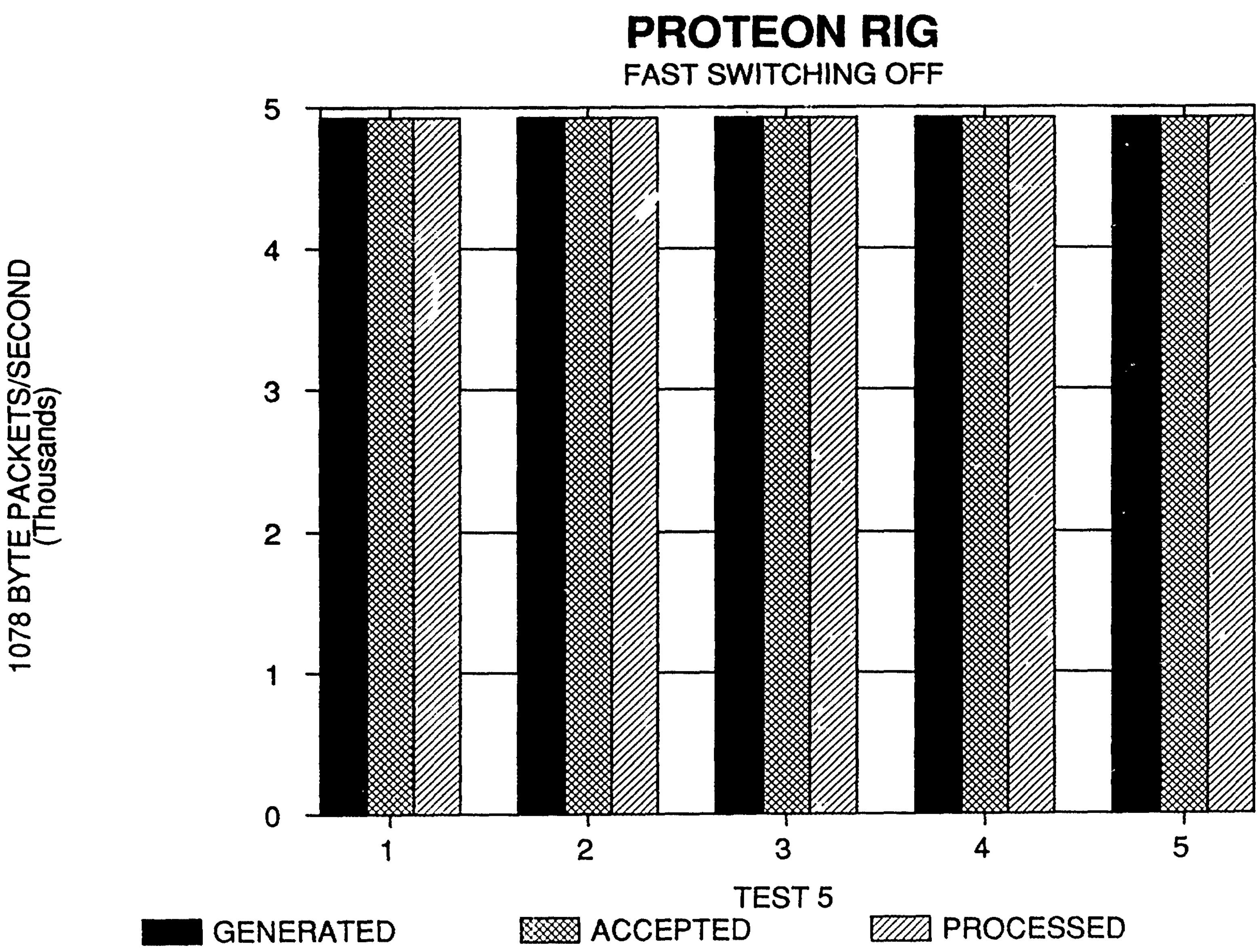

PROTEON RIG
FAST SWITCHING OFF
60 BYTE PACKETS/SECOND
(Thousands)
5
4
3
2
1
0
1
2
3
4
5
TEST 3
GENERATED
ACCEPTED
PROCESSED

(FIGURE 27)

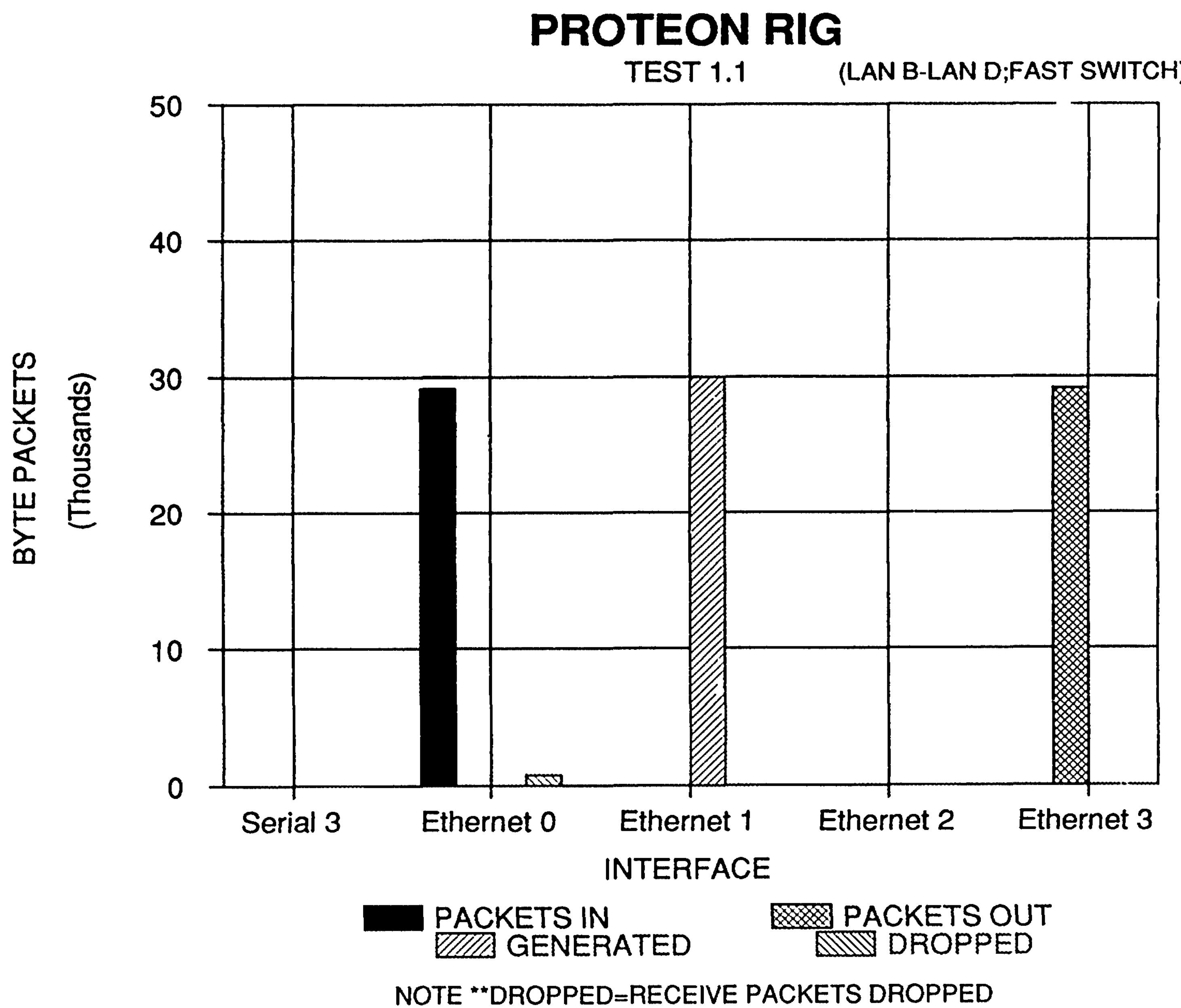


PROTEON RIG
FAST SWITCHING ON
1078 BYTE PACKETS/SECOND
(Thousands)
0
1
2
3
4
5
1
2
3
4
5
TEST 4
GENERATED
ACCEPTED
PROCESSED

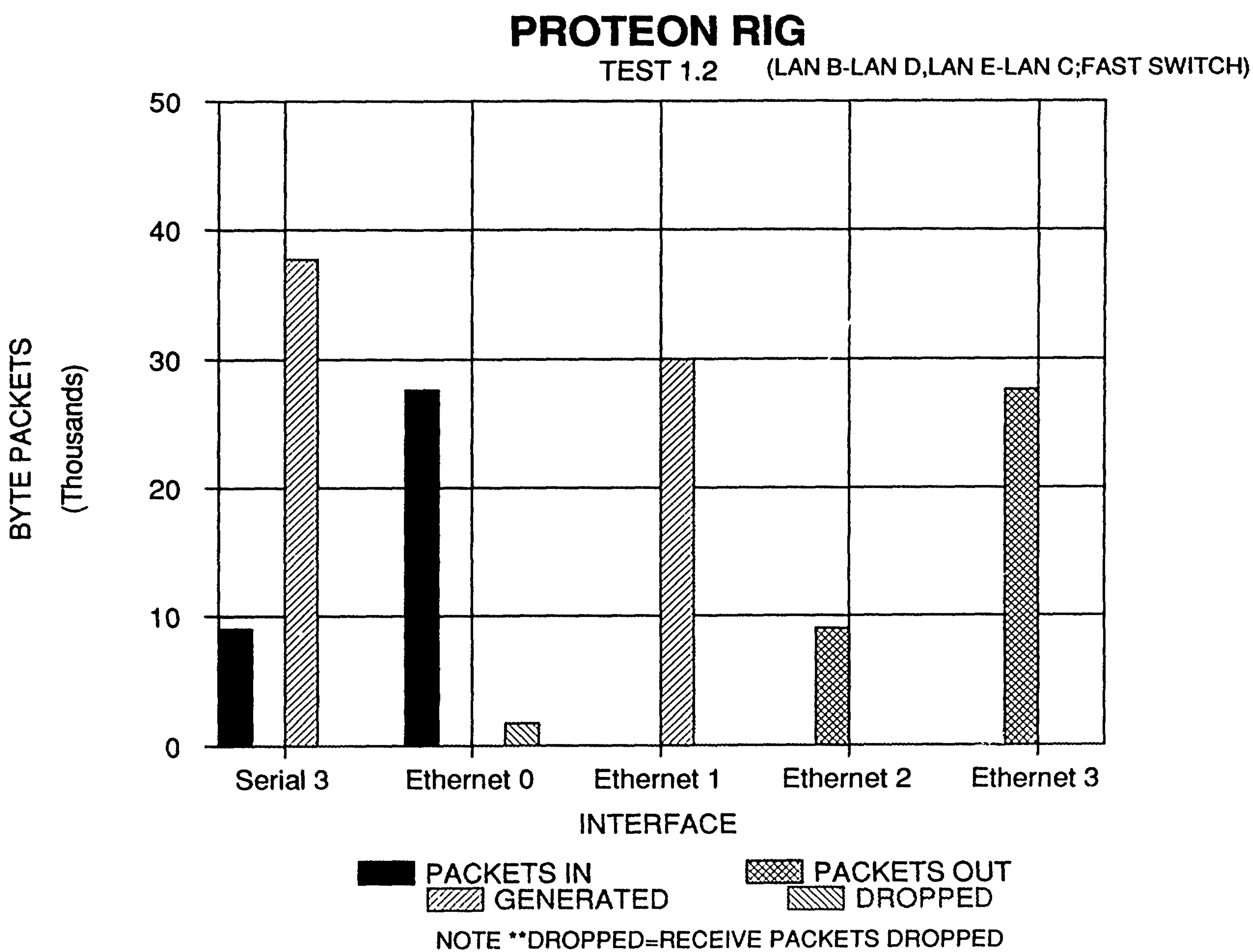
(FIGURE 28)


PROTEON RIG
FAST SWITCHING OFF
1078 BYTE PACKETS/SECOND
(Thousands)
0
1
2
3
4
5
1
2
3
4
5
TEST 5
GENERATED
ACCEPTED
PROCESSED

(FIGURE 29)


PROTEON RIG
TEST 1.1
(LAN B-LAN D;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

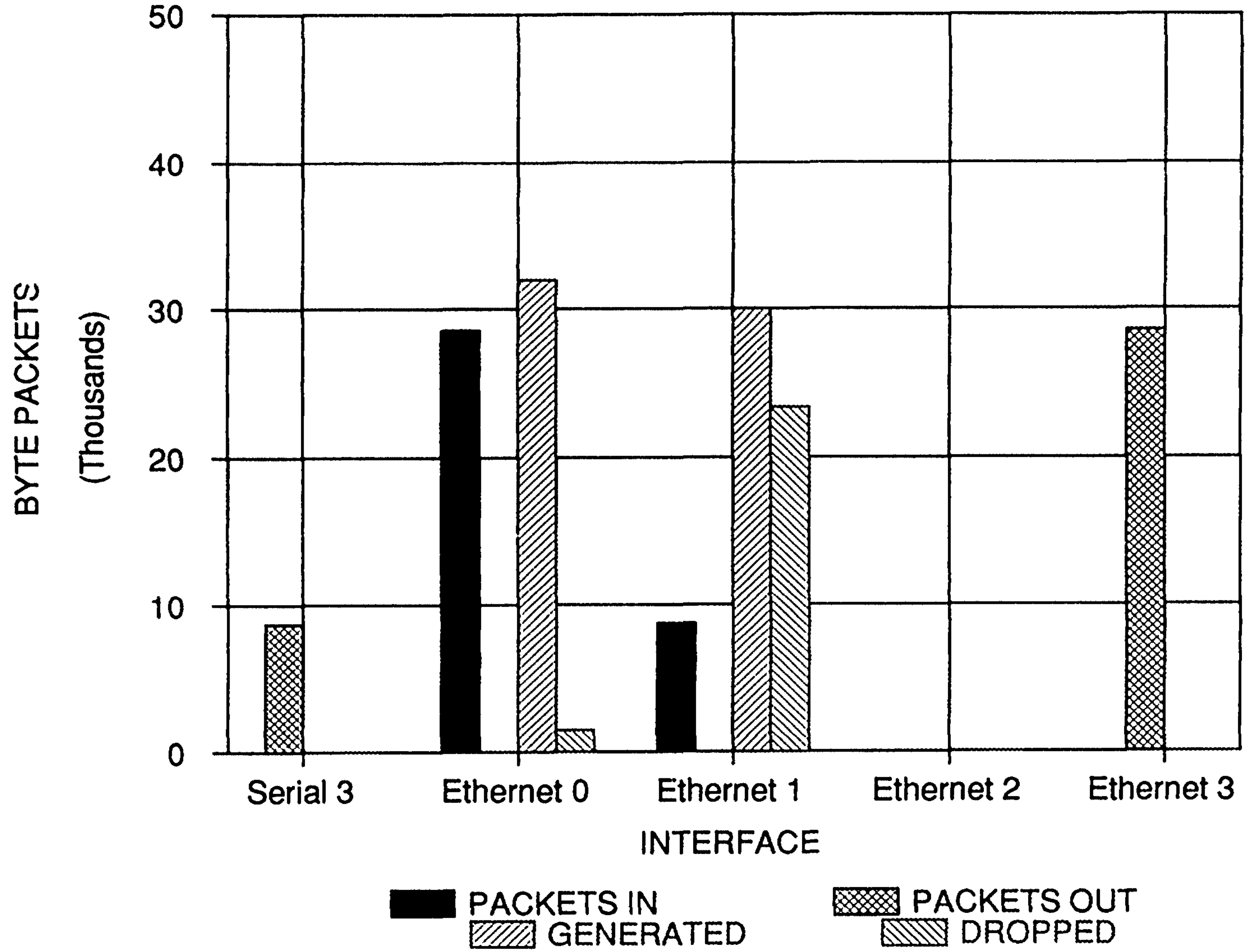
(FIGURE 30)


PROTEON RIG
TEST 1.2 (LAN B-LAN D,LAN E-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 31)

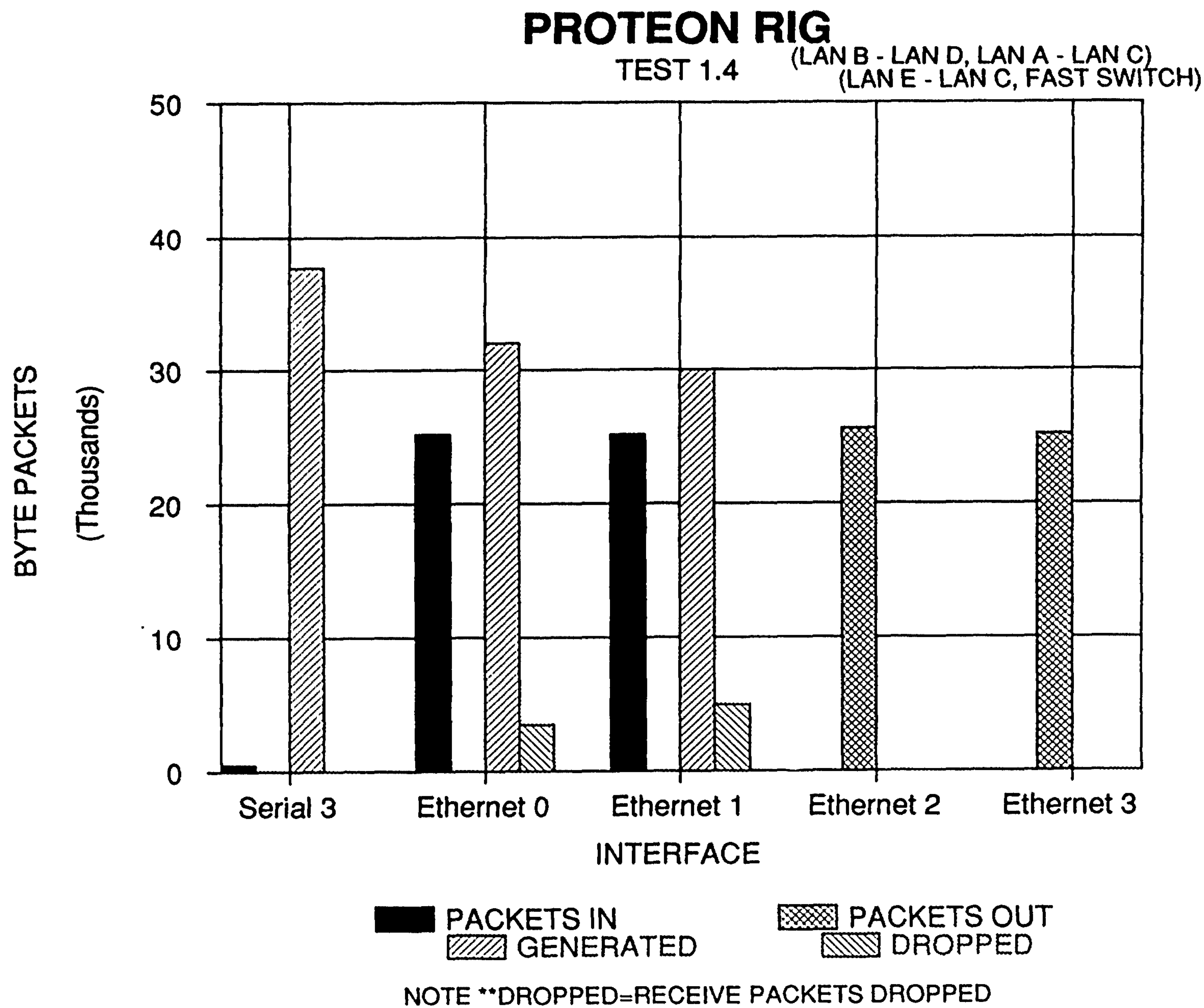
PROTEON RIG

TEST 1.3 (LAN B-LAN D,LAN A-LAN E;FAST SWITCH)

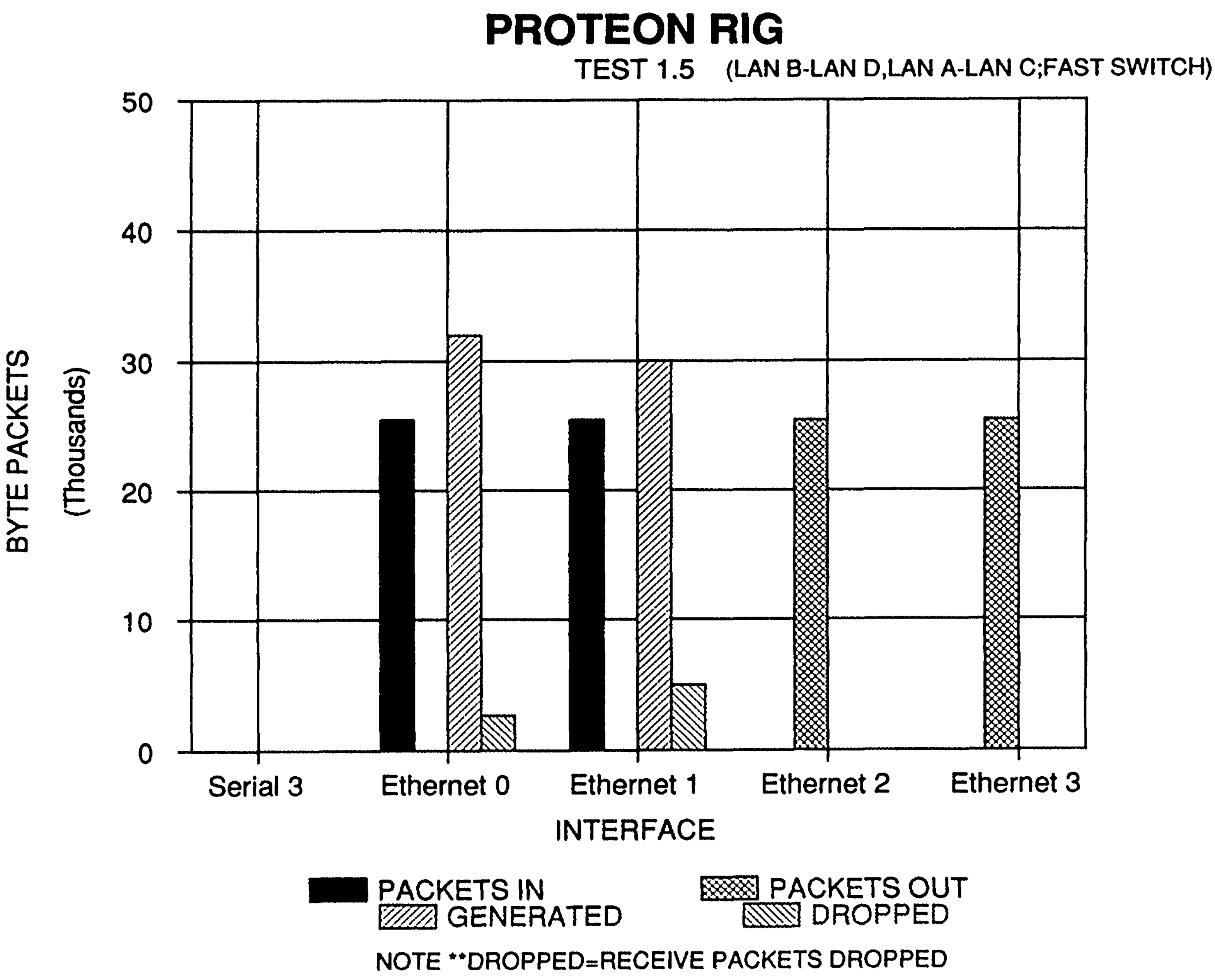


NOTE **DROPPED=RECEIVE PACKETS DROPPED

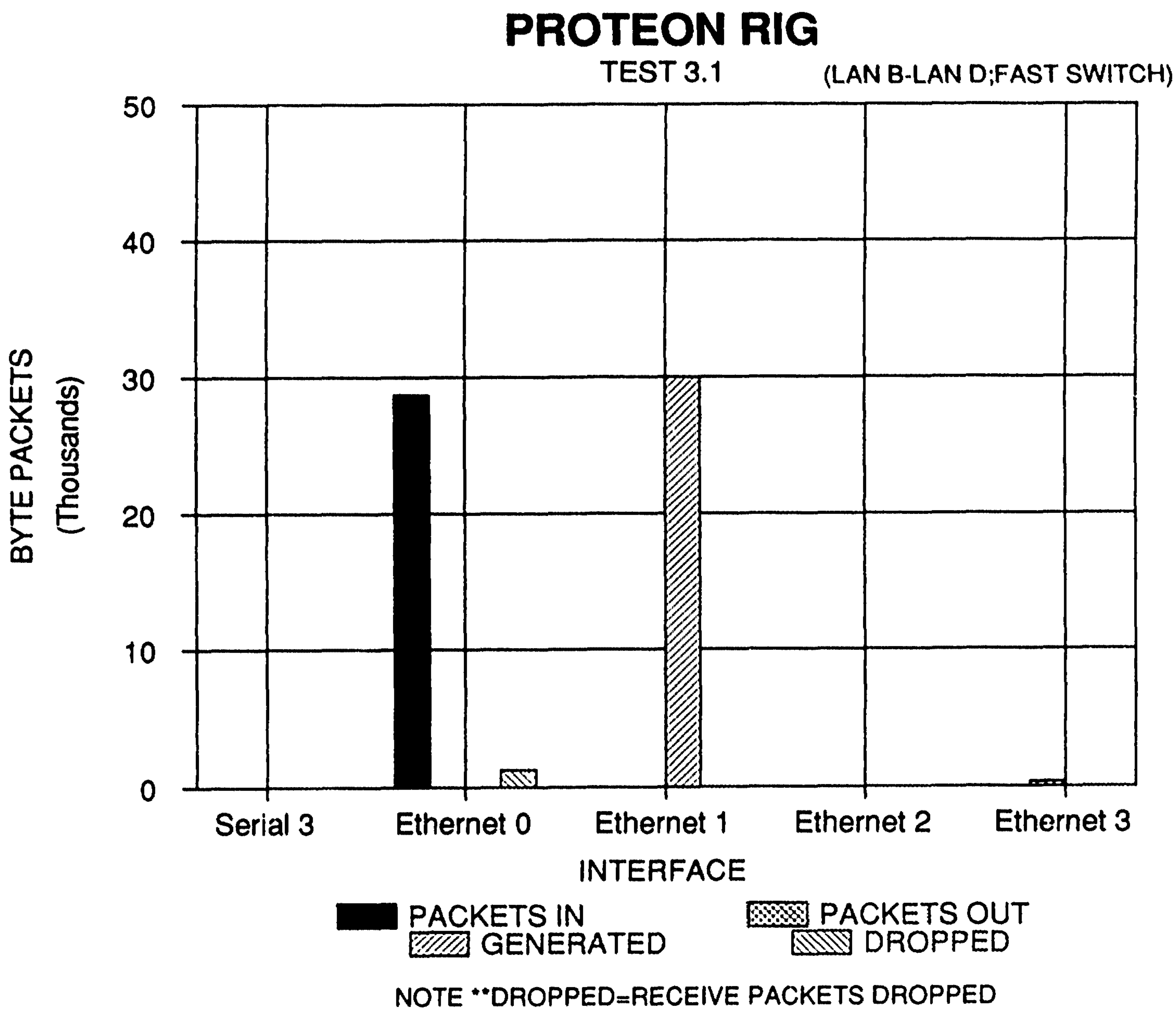
(FIGURE 32)


PROTEON RIG
TEST 1.4
(LAN B - LAN D, LAN A - LAN C)
(LAN E - LAN C, FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 33)

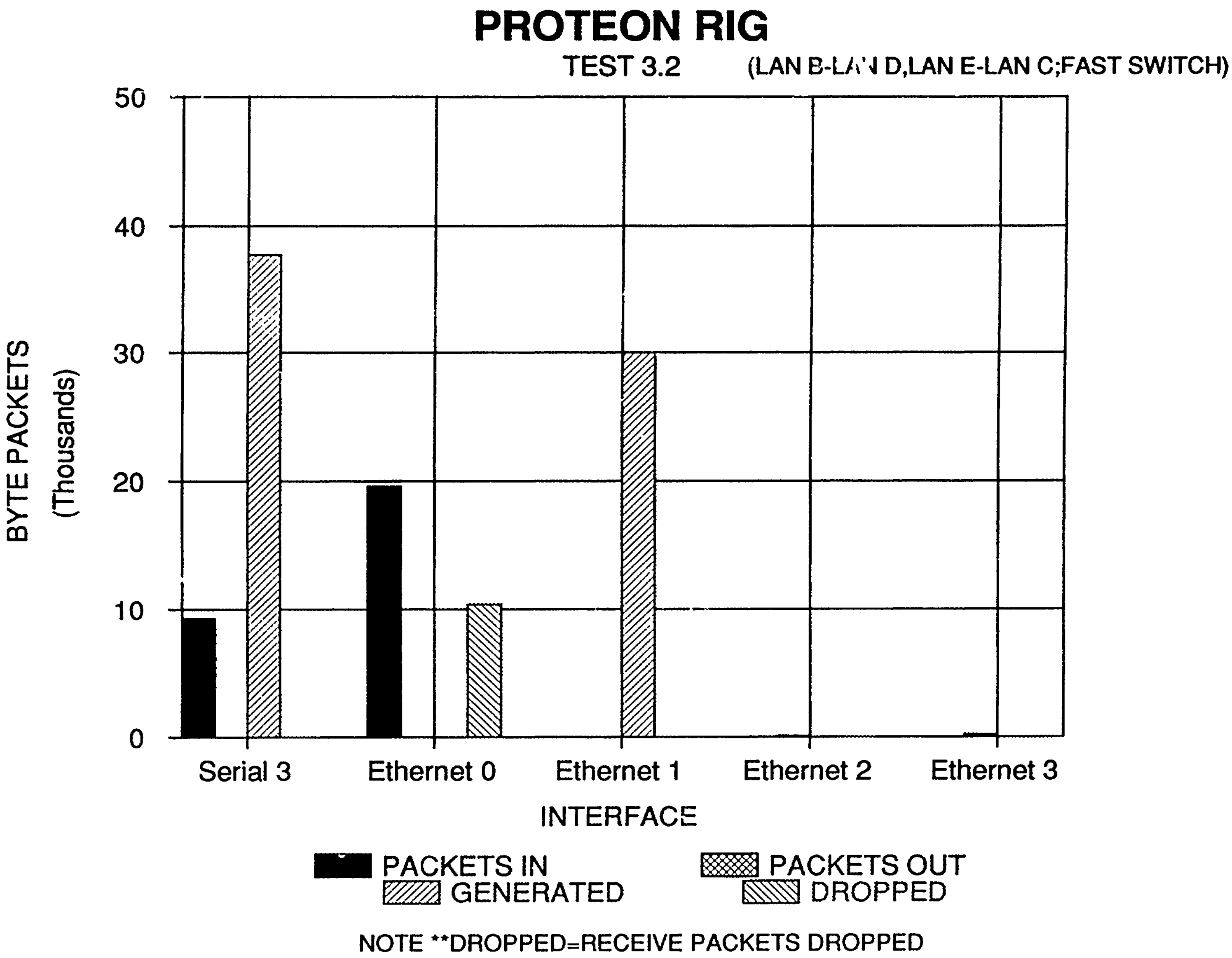

PROTEON RIG
TEST 1.5 (LAN B-LAN D,LAN A-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 34)

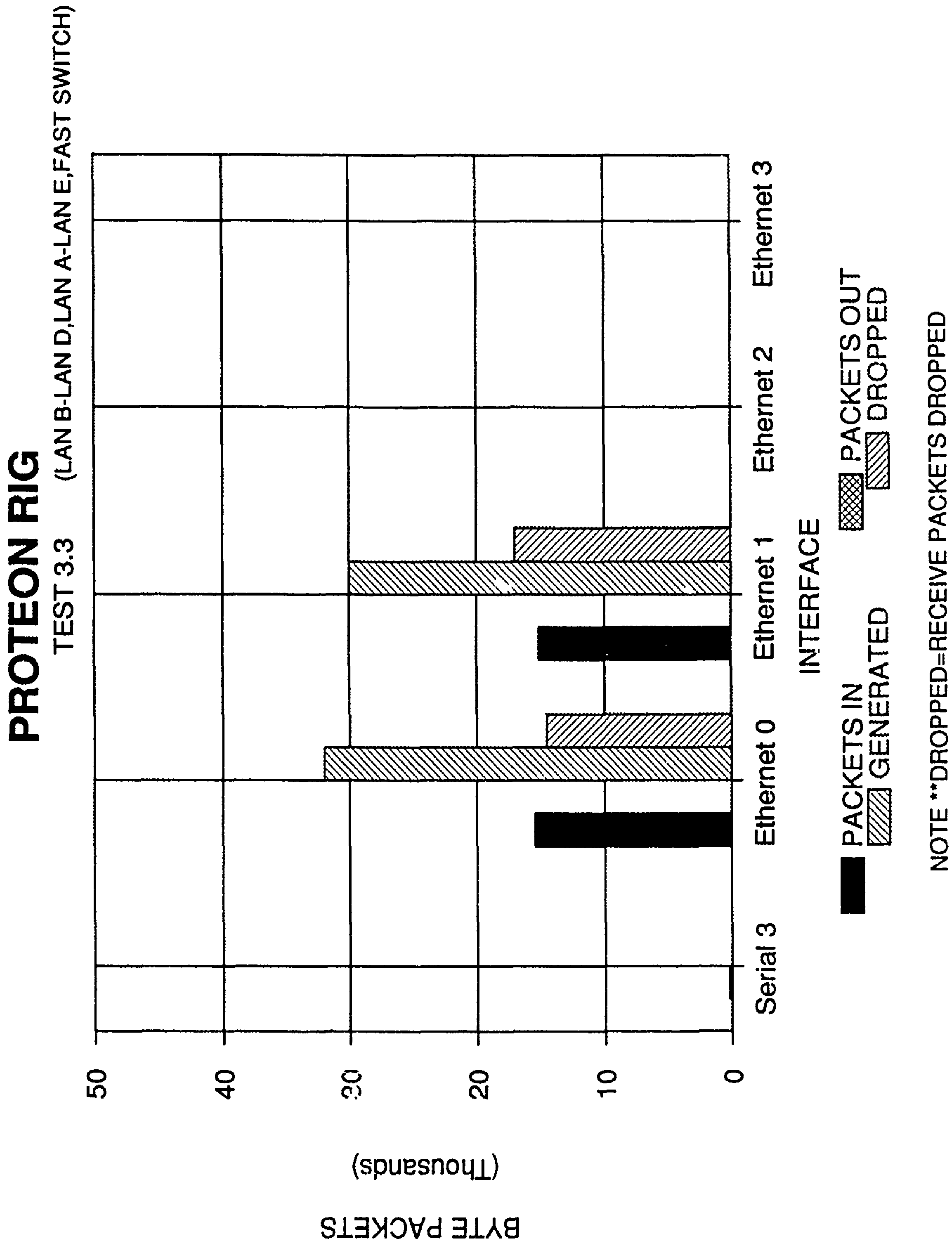


PROTEON RIG
TEST 3.1
(LAN B-LAN D;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

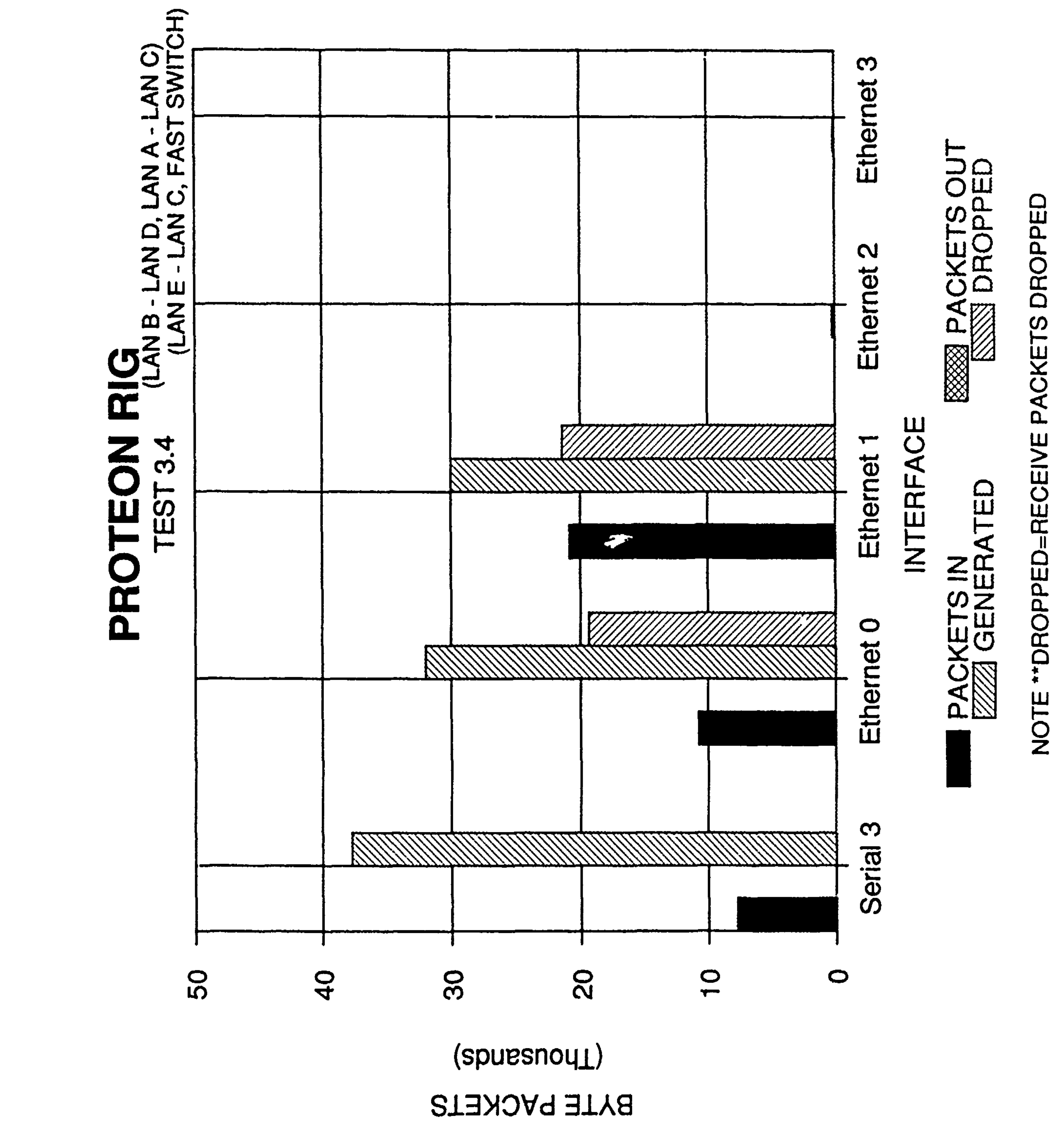
(FIGURE 35)


PROTEON RIG
TEST 3.2
(LAN B-LAN D,LAN E-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 36)

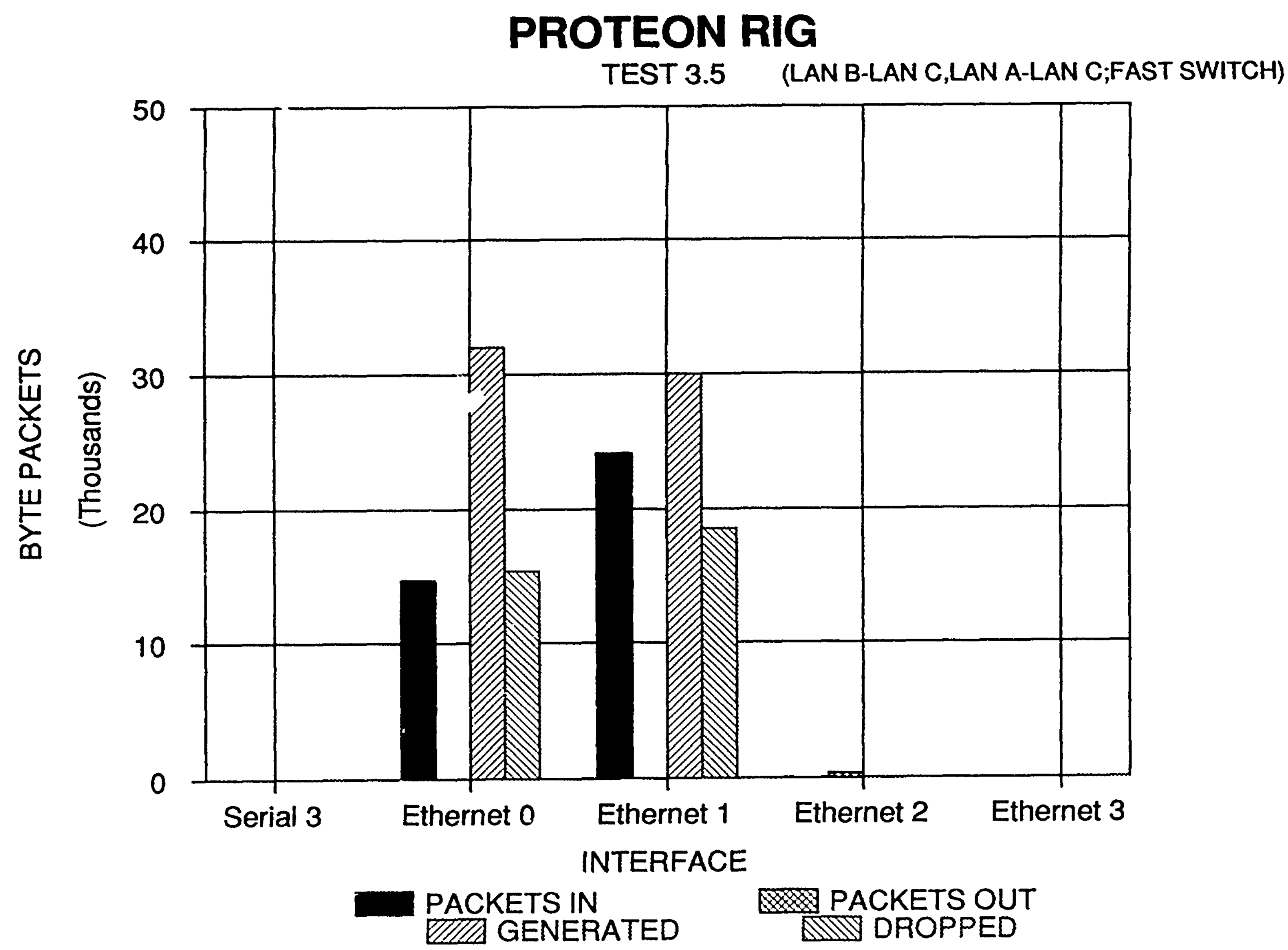

PROTEON RIG
TEST 3.3
(LAN B-LAN D,LAN A-LAN E,FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
PACKETS OUT
GENERATED
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 37)



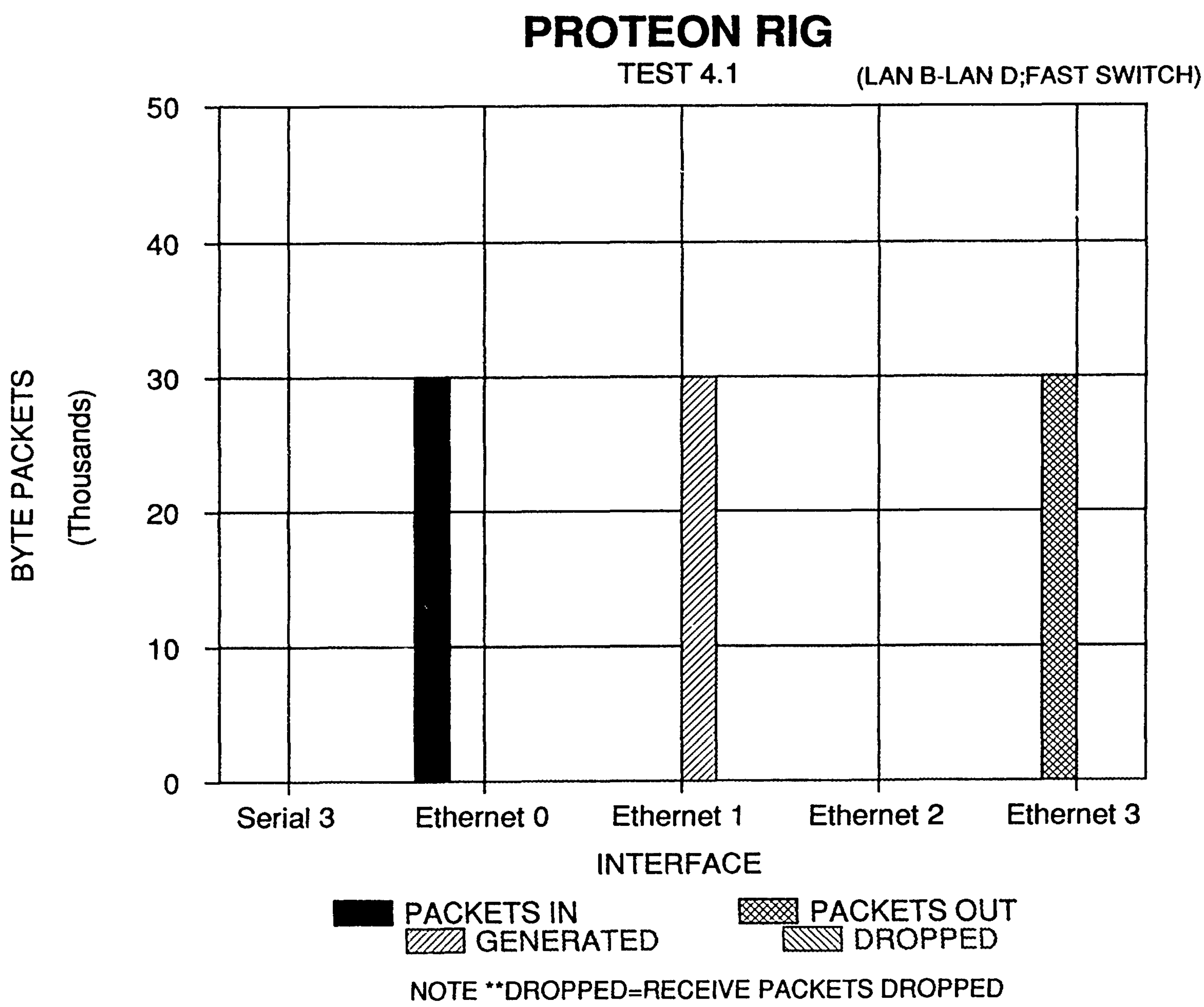
PROTEON RIG
TEST 3.4
(LAN B - LAN D, LAN A - LAN C)
(LAN E - LAN C, FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
PACKETS OUT
GENERATED
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 38)

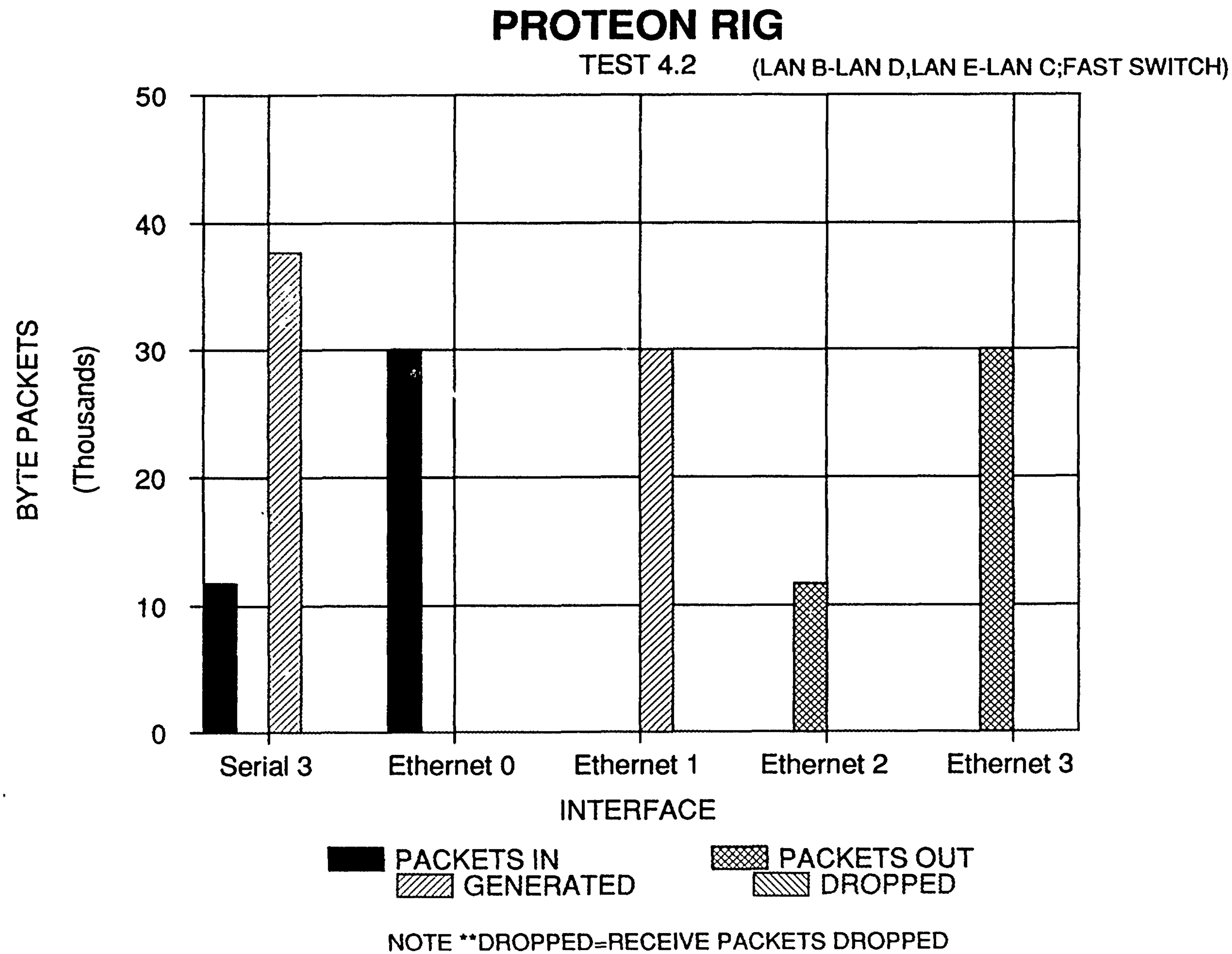


NOTE **DROPPED=RECEIVE PACKETS DROPPED

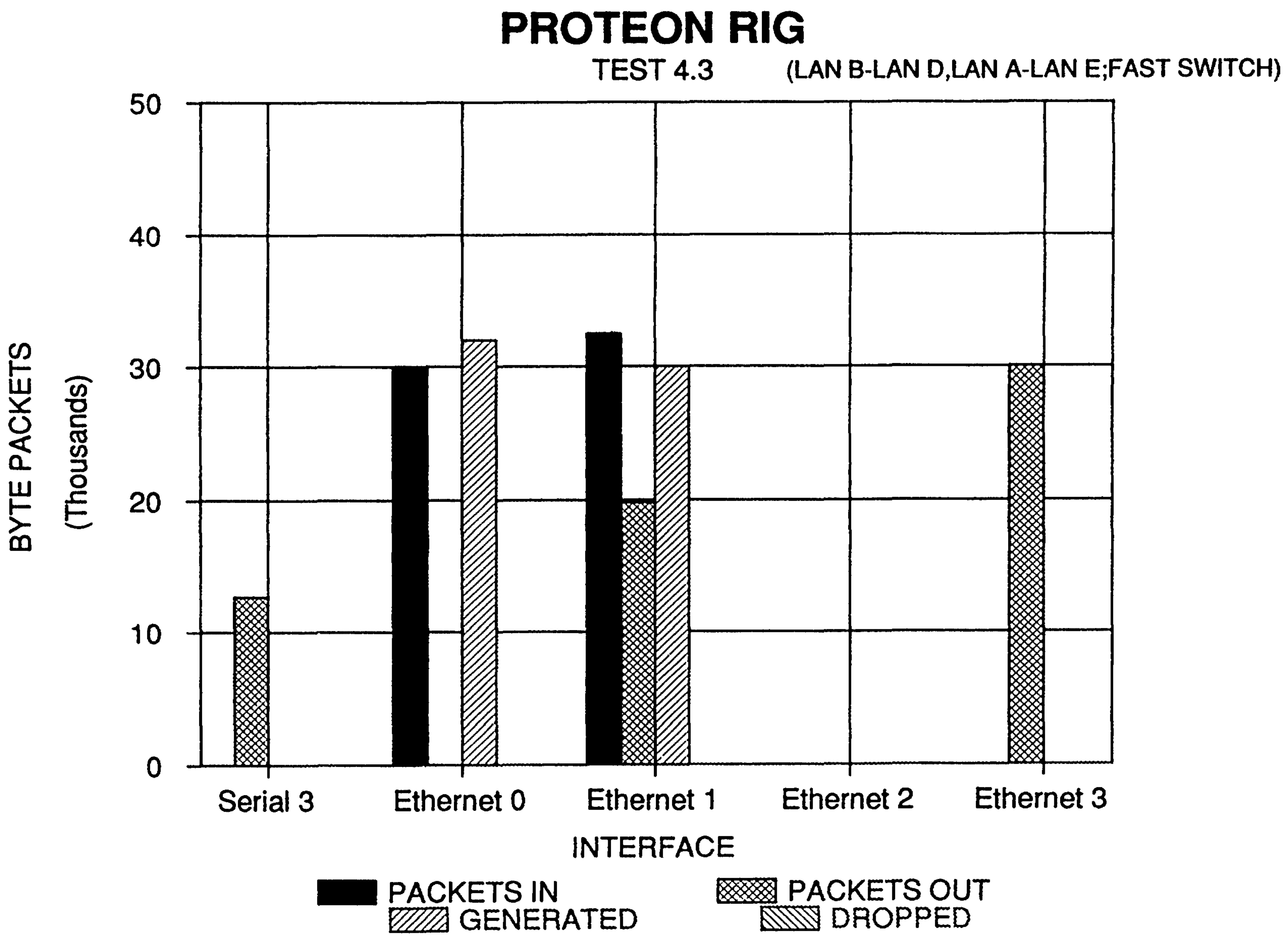
(FIGURE 39)


PROTEON RIG
TEST 4.1
(LAN B-LAN D;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 40)

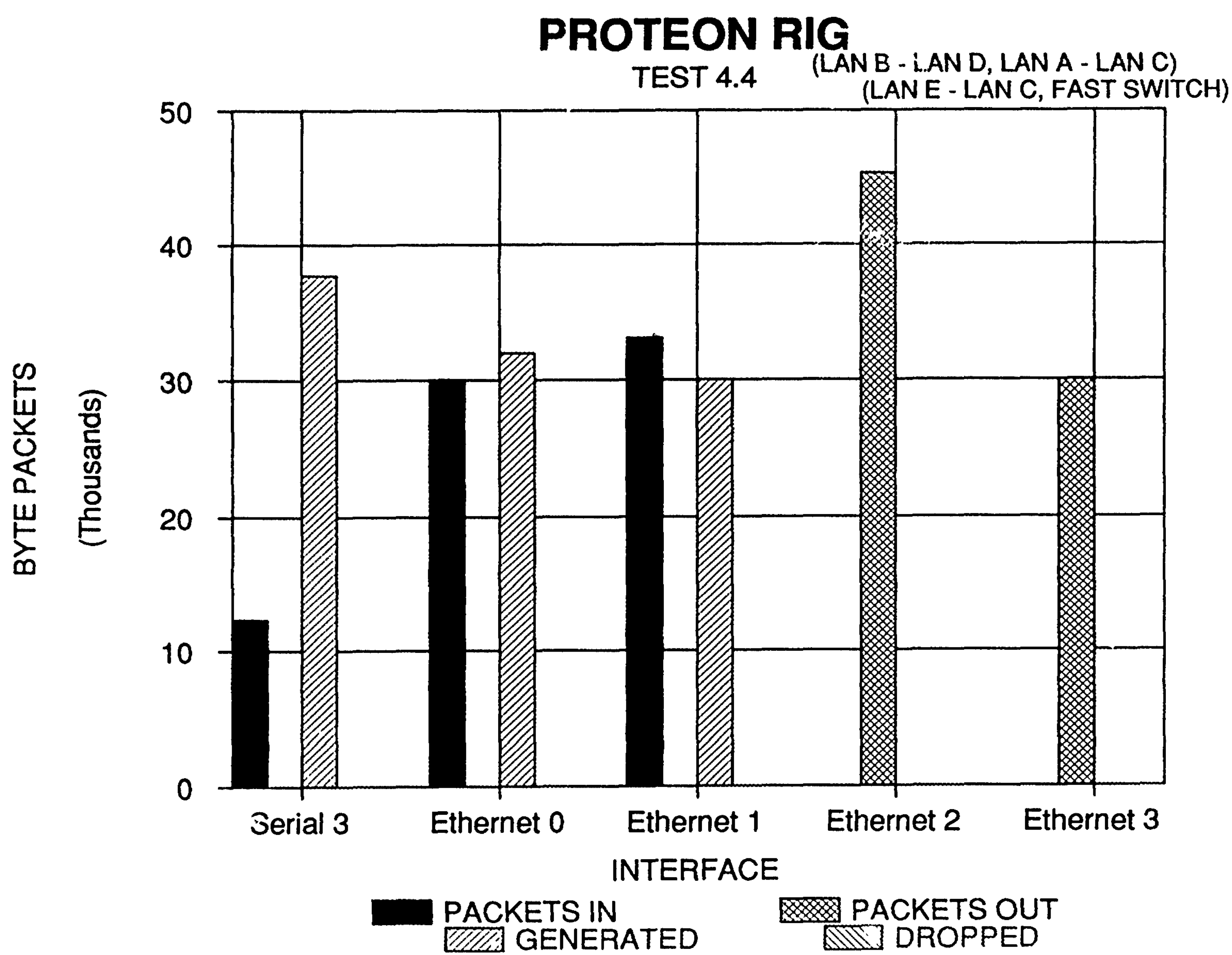

PROTEON RIG
TEST 4.2
(LAN B-LAN D,LAN E-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 41)



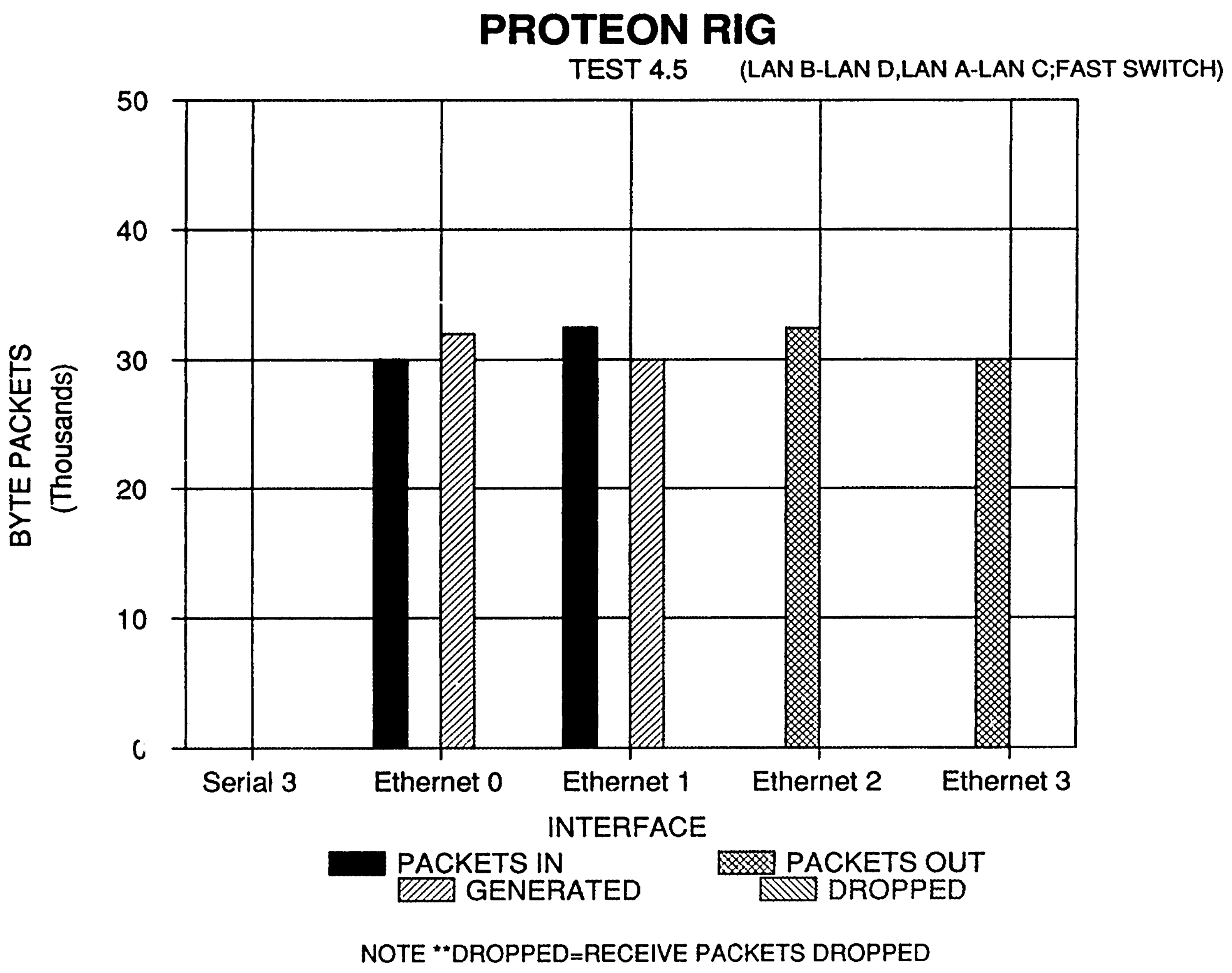
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 42)

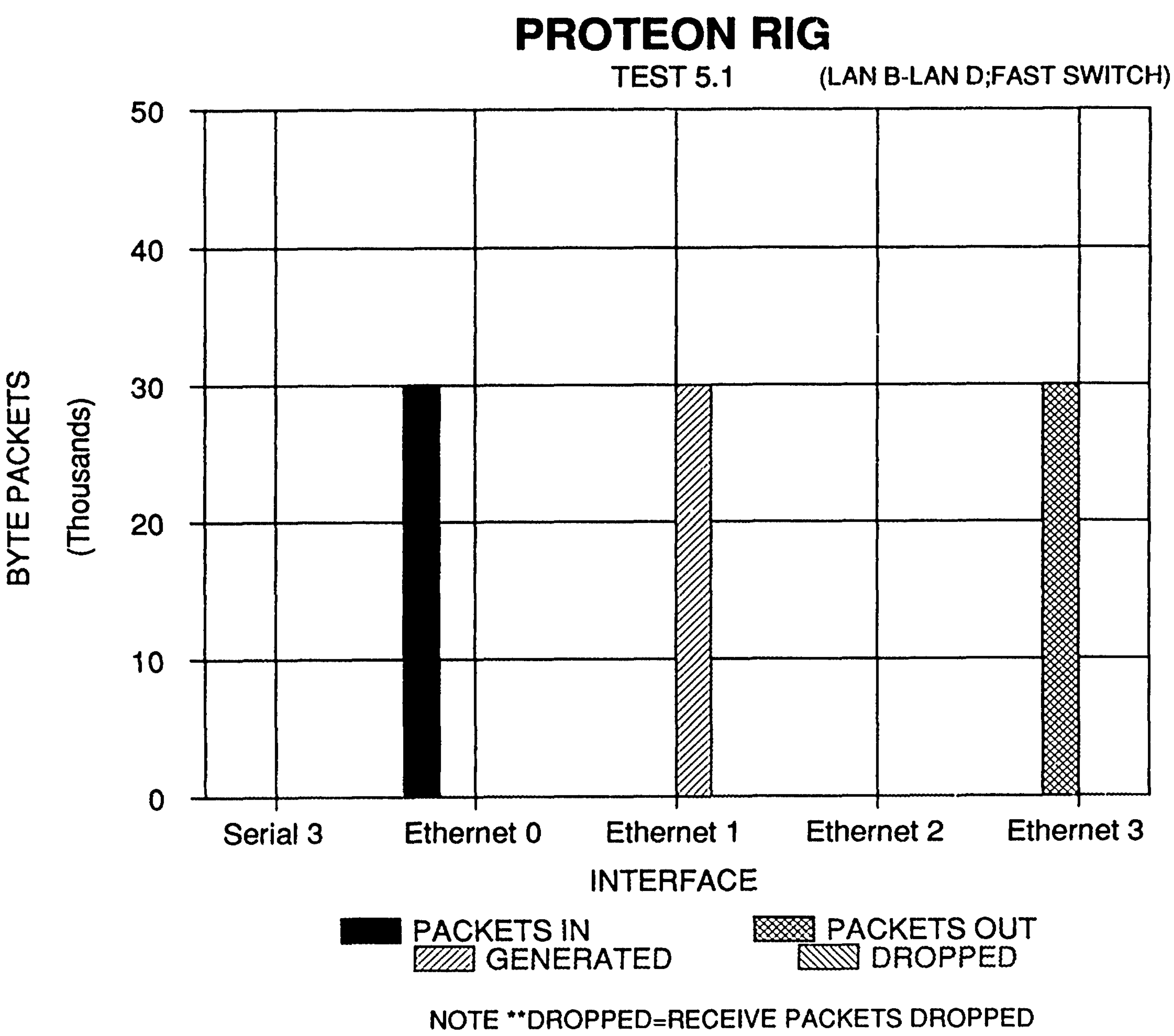


NOTE **DROPPED=RECEIVE PACKETS DROPPED

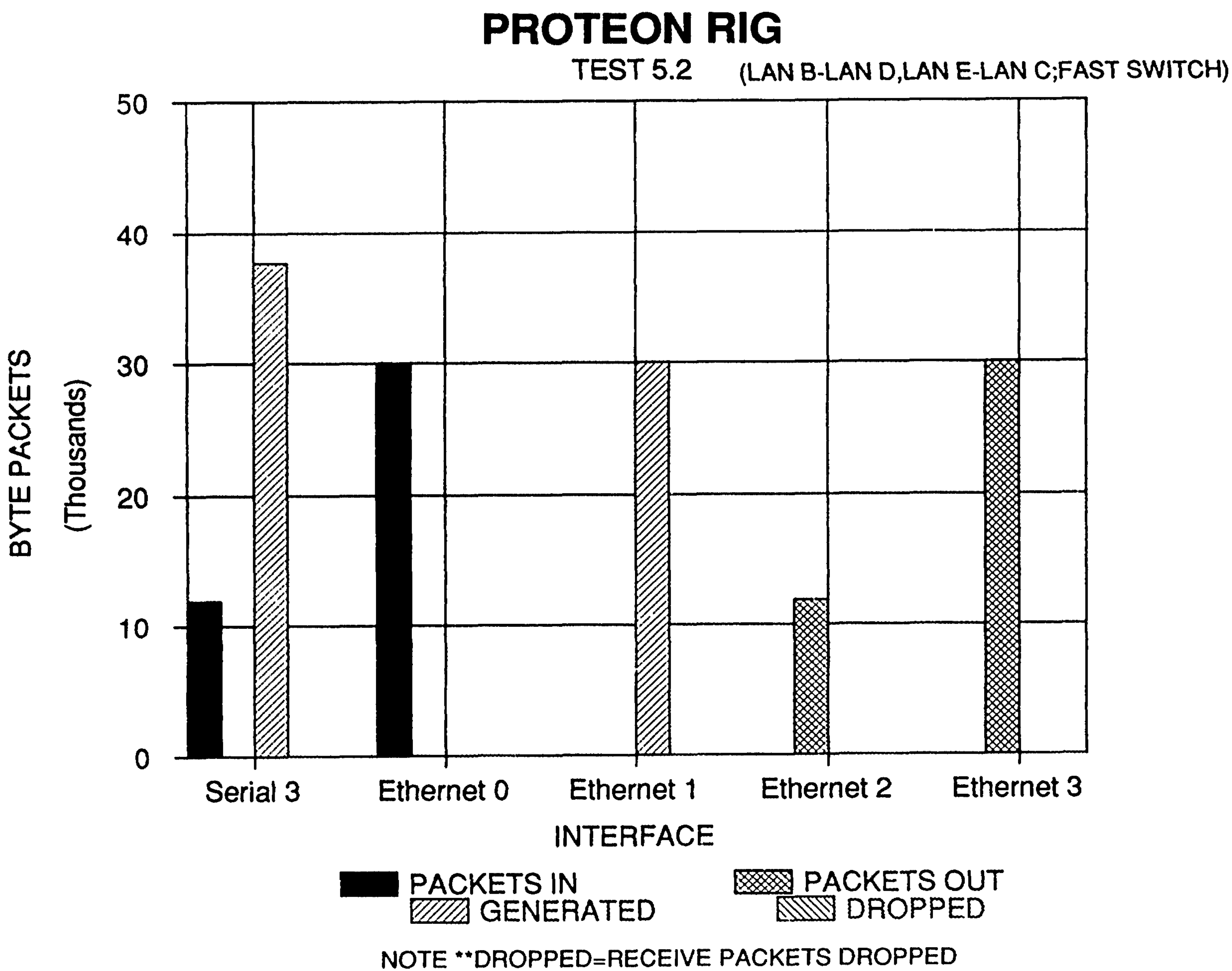
(FIGURE 43)


PROTEON RIG
TEST 4.5 (LAN B-LAN D,LAN A-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

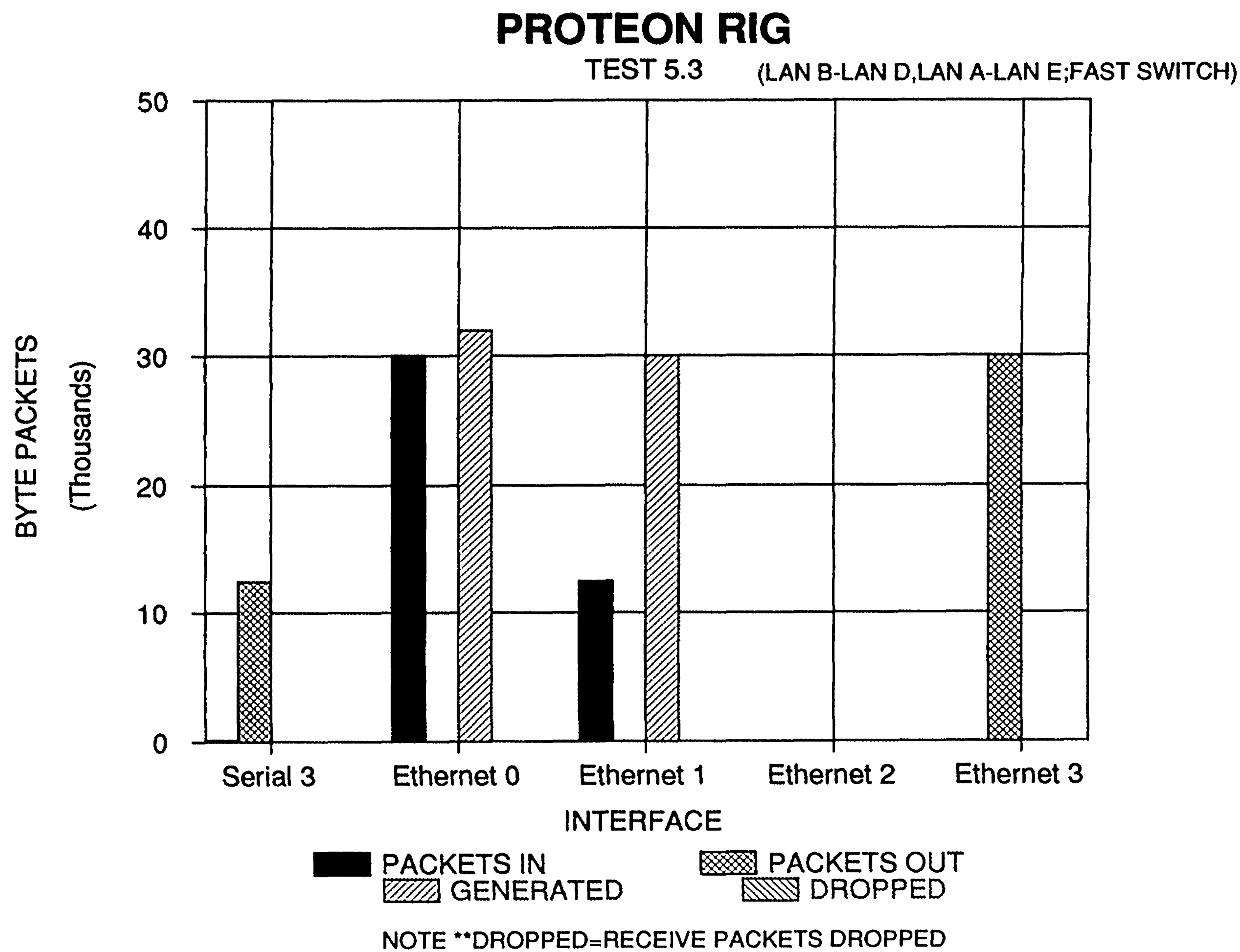
(FIGURE 44)


PROTEON RIG
TEST 5.1
(LAN B-LAN D;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

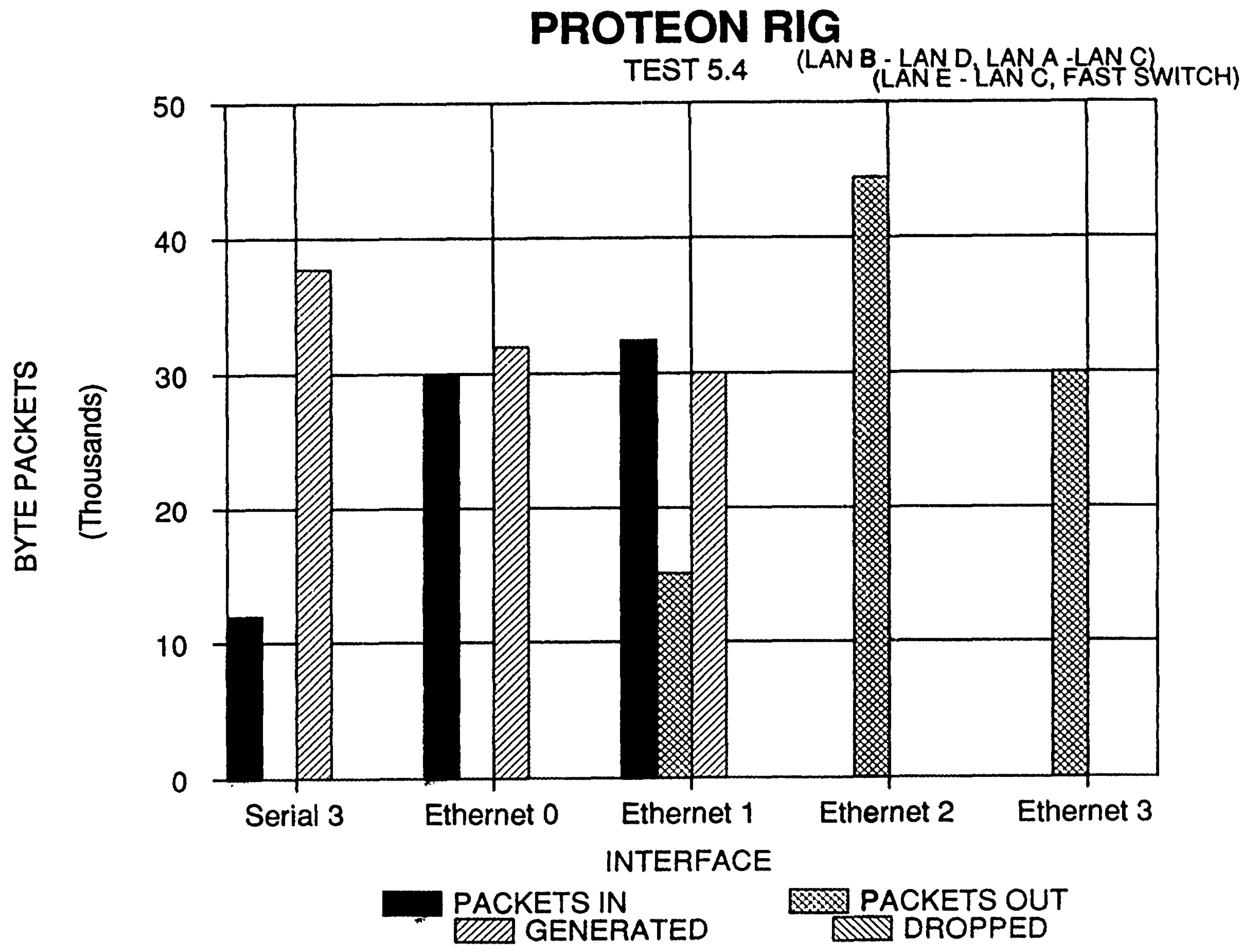
(FIGURE 45)


PROTEON RIG
TEST 5.2 (LAN B-LAN D,LAN E-LAN C;FAST SWITCH)
BYTE PACKETS
(Thousands)
50
40
30
20
10
0
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 46)


PROTEON RIG
TEST 5.3 (LAN B-LAN D,LAN A-LAN E;FAST SWITCH)
BYTE PACKETS
(Thousands)
0
10
20
30
40
50
Serial 3
Ethernet 0
Ethernet 1
Ethernet 2
Ethernet 3
INTERFACE
PACKETS IN
GENERATED
PACKETS OUT
DROPPED
NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 47)

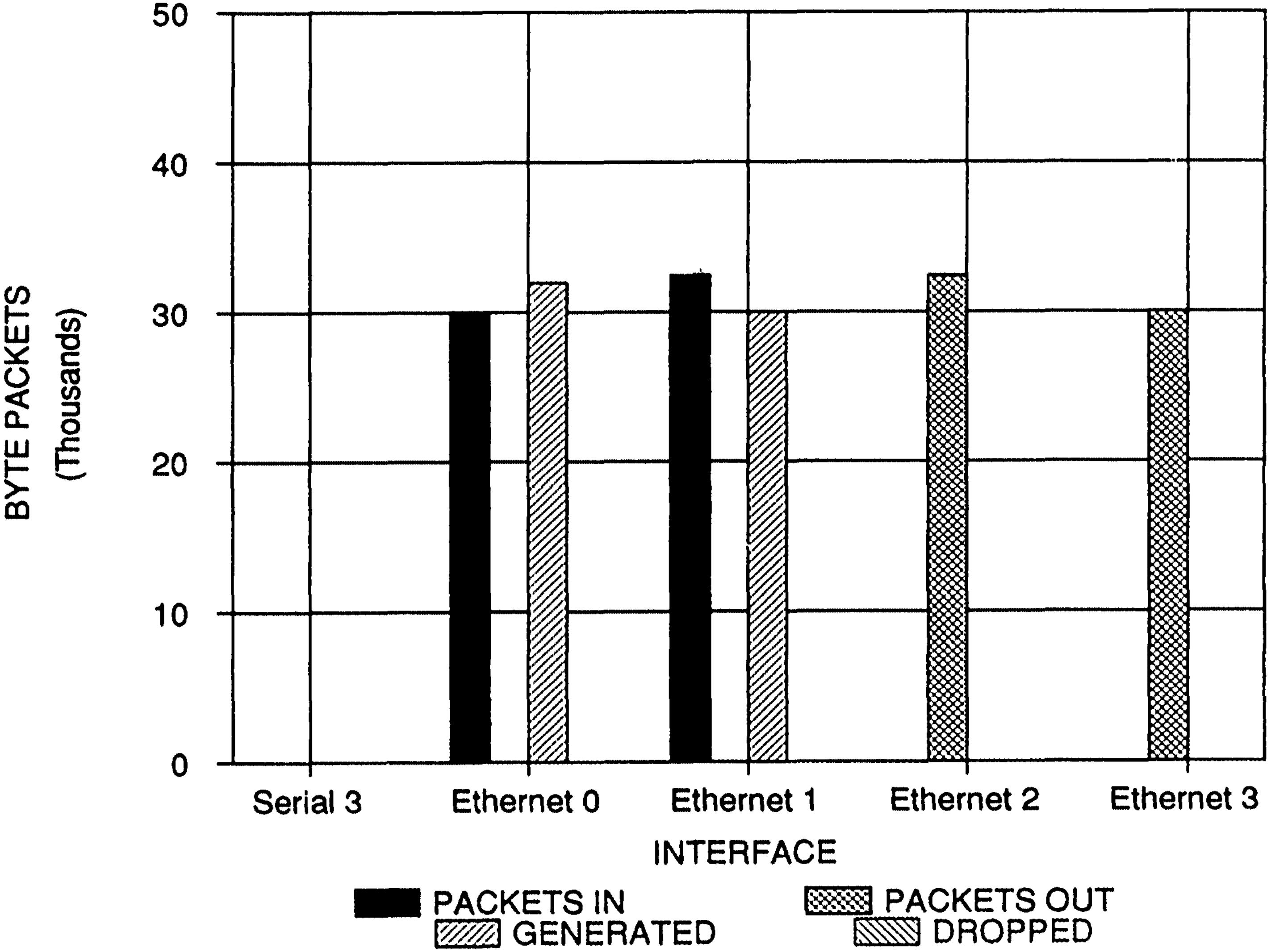


NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 48)

PROTEON RIG

TEST 5.5 (LAN B-LAN D,LAN A-LAN C;FAST SWITCH)



NOTE **DROPPED=RECEIVE PACKETS DROPPED

(FIGURE 49)

Appendices can be obtained from
UNIVERSAL ENERGY SYSTEMS, INC.

GEMACS VERSION 5.0 MODIFICATIONS AND APPLICATIONS

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High School Apprenticeship Program

Rome Air Development Center

Air Force Systems Command

Griffiss AFB, NY 13441-5700

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

1.0 INTRODUCTION

This report describes the work done by the High School Apprentice in RBCT during the summer of 1990. This work was primarily concerned with the revision and utilization of the Electromagnetic Environmental Effects (E3) program, General Electromagnetic Model for the Analysis of Complex Systems (GEMACS). The tasks regarding the GEMACS program consisted of generating a release version of the program, updating and debugging the code, the validation of test cases, and producing simulation models for GEMACS analyses using the Graphical Aids for the Users of GEMACS (GAUGE) tool.

In the newly acquired Version 5.0 GEMACS program, certain statements could not be understood by all mainframe computer systems. These statements needed to be replaced by equivalent language to allow compatability to nearly all mainframes. Once a releasable version of the program was generated, test cases were run for assurance that the version ran correctly. In addition to this, work was done in reviewing user problems with GEMACS. This work ultimately led to the definition of unforeseen limitations of the GEMACS program.

By using the GAUGE tool, two models of the RC135

aircraft were generated. One of these models was extremely simple and the other was more complex. These models were to be tested for vulnerability to electromagnetic threats, using the new version of GEMACS. A simple dipole placed above each model, acted as the electromagnetic source. The cases were then submitted to GEMACS, and results were obtained. The results were then compared to determine whether similiar outputs could be acquired. If so, then the simple model could be run instead of the more complex one. This would save the government significant amounts of time and money.

2.0 GEMACS

2.1 OVERVIEW

GEMACS is a user oriented, general purpose code, which is designed to incorporate many techniques in simulating complex electromagnetic systems. The program is designed for experienced electromagnetics analysts, with knowledge of applied linear algebra [1].

The program consists of six executable FORTRAN programs. These programs, called modules, are Geometrical

Theory of Diffraction (GTD), Method of Moments (MOM), Finite Differences (FD), Input, Solution, and Output. The GEMACS code uses high level language and provides flexiblity over the computational sequences, for ease to the user. The program also contains many debug features to help the user in identifying and locating errors.

2.2 GENERATING RELEASE VERSION OF GEMACS 5.0

Recently version 5.0 of the GEMACS program has been delivered to the Rome Air Development Center (RADC). Its increased capabilities and capacities are currently being assessed at RADC/RBCT. GEMACS 5.0 is a very portable code, but the edition given to RBCT is designed to run on a DEC MicroVAX system. In various subroutines of the program there are "include" statements which refer to often called upon command strings, known as common blocks. Include statements allow each command to be written only once per subroutine and then refered to multiple times. This shortens the code and makes it much easier to read and write. Some computers, other than a VAX system, may not be able to process this statement. If the GEMACS program is to be distributed to Department of Defense (DoD) contractors for use, it must be able to run on a variety of systems. To fix this, the include statements must be replaced by the common block that they represent. The task

is simple, yet rather tedious.

Since the common blocks exist as separate files all residing in a single directory, the first step was to put all of the common blocks into one file. This would provide one file that could easily be copied from one module directory to another, cutting down on work time tremendously. Once this file was in all of the module directories, it was then appended to each of the files containing the include statement; nearly 400 of them. The include statements in each subroutine were then replaced by the appropriate common blocks using the cut and paste utility in the editor. The remaining common blocks at the end of the file were then deleted.

Once the files were edited they then had to be recompiled. The files were compiled using a batch file. Batch files are noninteractive processes that perform the desired task in the background [2]. This allows the user to execute other tasks at the same time. This saves a large amount of time. If there were no errors, an object file was created from it. If there was an error, then no object file was created. To correct the error the user must examine the .LIS file. Compile errors are denoted in the .LIS files, making the program much easier to use. When the error was found, the FORTRAN file was then repaired and

recompiled. Usually the error consisted of no more than a typographical error or an include statement that had been forgotten. Using another batch file, a library was created in each module. Then the object files were linked, using yet another batch file. From the linked files an executable was generated for each module. The .EXE files were now ready for use.

To insure that this release version was working properly, test cases, which had been previously validated, were run through the program. The cases varied from open ended waveguides to impedance loaded arrays of quarterwave dipoles. The results were obtained and then compared to the results of the same tests run through the edition of GEMACS 5.0 delivered to RADC/RBCT. The outputs were the same, therefore the program was ready to be distributed.

2.3 UPDATES TO GEMACS CODE

Occassionally, updates to the code are neccesary. These updates are usually fixes to the code. The originator of the GEMACS program, Edgar L. Coffey, issues the updates. Upon receiving a packet of updates, the changes were incorporated into the release version of the program. The program was then recompiled. Once again, the previously validated test cases were rerun to make sure

the changes were inplimented properly.

3.0 ELECTROMAGNETIC SIMULATION

3.1 OVERVIEW OF GAUGE PROGRAM

Graphical Aids for the Users of GEMACS (GAUGE), is a program designed to provide a graphical interface for GEMACS users [3]. The GAUGE program allows the user to develop and visualize geometry input for GEMACS. GAUGE is written in the FORTRAN 77 language, except for a few auxiliary files, which are written in Turbo Pascal. The program also allows the user to generate two-dimensional plots of GEMACS results.

3.2 OBJECTIVES OF SIMULATIONS

The task, using the GAUGE tool, was to develop scale models of the RC135 aircraft, for a runtime/data quality tradeoff analysis. This is necessary due to future simulation work using the RC 135 models. Two models were developed of the RC 135, for a resource comparison. One model was simple and the other was more complex. A simple dipole was used as the radiating element. Each input deck to GEMACS containing the dipole and the model geometry was run through GEMACS. The results were then compared, to see

if similiar data could be obtained by using a simplier model with less run time.

3.3 MODEL CONSTRUCTION

Although the GAUGE/GEMACS interaction is a versatile one, it does have its limitations. The cases were to be run at a very high frequency, 9.7 GHz, so many problems arose because of this. Method of Moment wire models were to be developed first. These wire models became an impossibility due to the fact that GEMACS requires that wire segments be approximately .1 wavelength in length. The wavelength is obtained through the following formula.

$$\text{Lambda} = c/f \qquad (1)$$

Lambda = wavelength in meters

c = speed of light (3.0 E08 m/sec)

f = frequency in hertz

As one can see, this does not allow the wire segments to be over a third of a centimeter long. With such small segments, over 2,000 wires were created just in the nosecone of the plane. GAUGE will only process 1,500 segments at one time. The models could have been done in several pieces and then assembled before being run through

GEMACS, but it was much too difficult to do it this way.

The next step was to try developing the models using Geometric Theory of Diffraction plates and cylinders. The plates and cylinders have no restrictions on length concerning the frequency. GAUGE places different types of limitations on GTD geometry. Using GTD the simple model was developed by constructing a long cylinder with plates for wings. See Figure 1. GAUGE was easily applied to the development of this model. The more complex model was constructed using a cylinder for a fuselage, and plates for wings, tail structure, nosecone, and tailcone. When the complex model was drawn, GAUGE refused to acknowledge the plates of the nosecone and tailcone. After reading the GEMACS Source book, the problem was discovered [4]. In GEMACS there are certain limits on what types of geometry items can be connected, and in what position they are connected. No plate to endcap connections are allowed. This presented yet another problem. If no plate to endcap connections are allowed and cylinders can not exist without endcaps, then the cylinder must be deleted. It was decided that the best way to go would be an all plate model. The all plate model was then developed using GAUGE. See Figure 2.

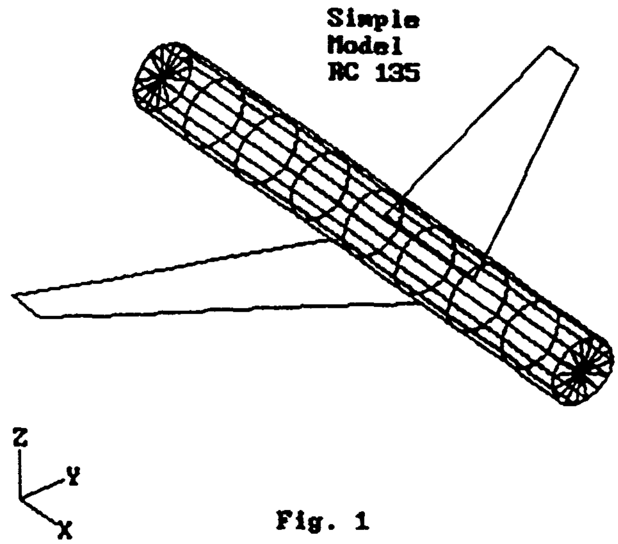

Fig. 1

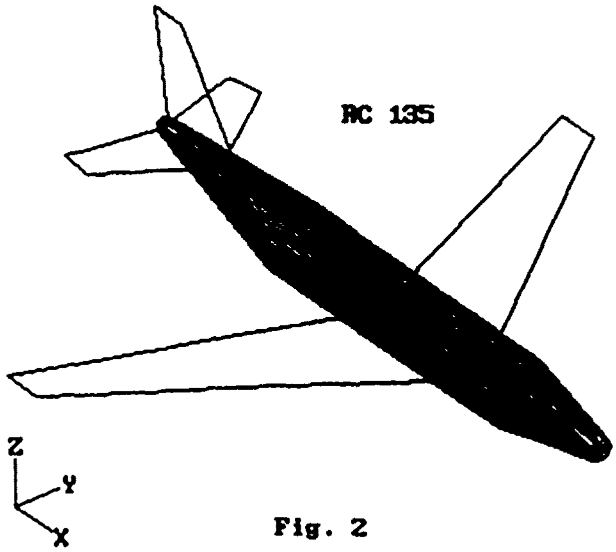

Fig. 2

3.4 INPUT DECK FOR GEMACS

Before GEMACS can understand the GAUGE geometry, a list of commands, called the input deck, must be formed. In the input deck the user describes to GEMACS the specific details of the simulation that is to be run. Above the RC135 models a dipole was placed. The dipole, emitted at a frequency of 9.7 GHz and had a voltage feed of 1000V. When the cases were run, various error messages resulted indicating that there was a problem with the input deck. One item at a time was changed, in an attempt to locate the error. A debug option was put in to assist in locating the error. The errors were found and corrected. The conductivity of the plates was set to the wrong value, which caused the errors.

3.5 SIMULATION OUTPUTS

After both cases had been run through GEMACS, the files had to be transferred back to GAUGE for visual outputs. Before graphical aids can be obtained, the GEMACS output file must be processed so that GAUGE can interpret the information. This is accomplished by using a program called GMOUT. By generating two-dimensional plots of both the elevation and azimuthal cuts for both models, the results can be compared graphically. The results could

also be compared numerically through the output files in GEMACS. See figures 3 and 4, noting that 0 degrees is at the nosecone, 90 degrees is postioned over the left wing, and 180 degrees is located at the tail of the aircraft. Since the dipole and aircraft models are symmetrical only half of the antenna pattern need be displayed. The problem was approached in this manner in order to cut down on the runtime of the cases. Originally, the complex model took one week to run, compared to the two hour runtime of the simple model. Taking into consideration that the results would be identical for both sides of the aircraft, and that creeping waves around the fuselage of the aircraft would be minimal, the complex model was cut in half. This reduced the runtime to four hours.

It was no surprise that the patterns were different. The assumption that the pattern of the more complex model is more accurate is reasonable. However,the results of the simple model can be considered valid under certain circumstances. In interpreting the data received, we find that both results have similiar trends. On the average, the simple model was 50 V/M higher in the azimuthal plane, than was the complex model. In the elevation field, the simple model was approximately 52 V/M higher. In this case both the simple model and the one half complex model had reasonable runtimes, with a significant difference in

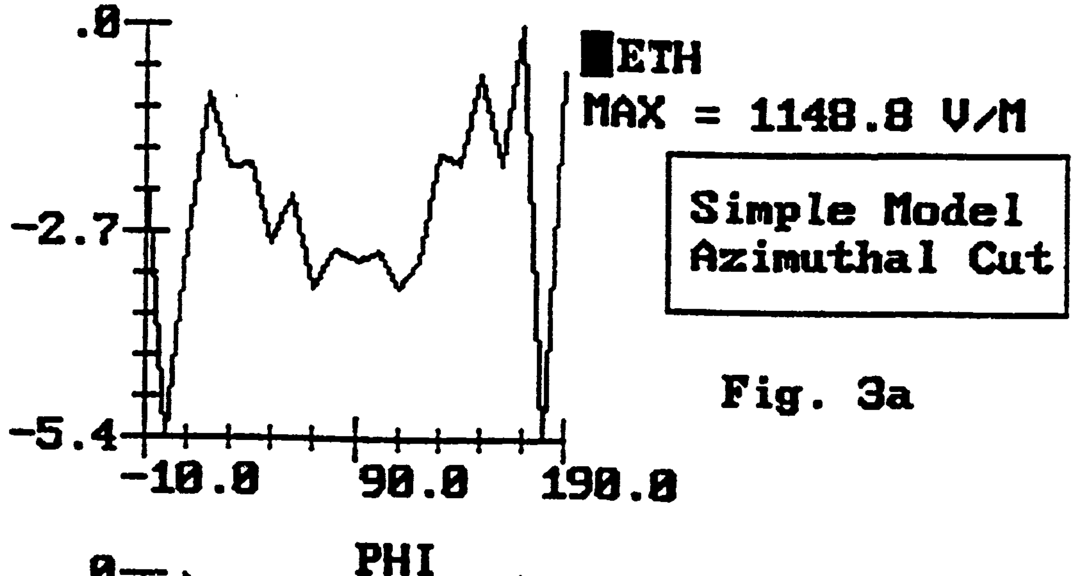
.0
-2.7
-5.4
-10.0
90.0
190.0
PHI
ETH
MAX = 1148.8 V/M
Simple Model
Azimuthal Cut

Fig. 3a

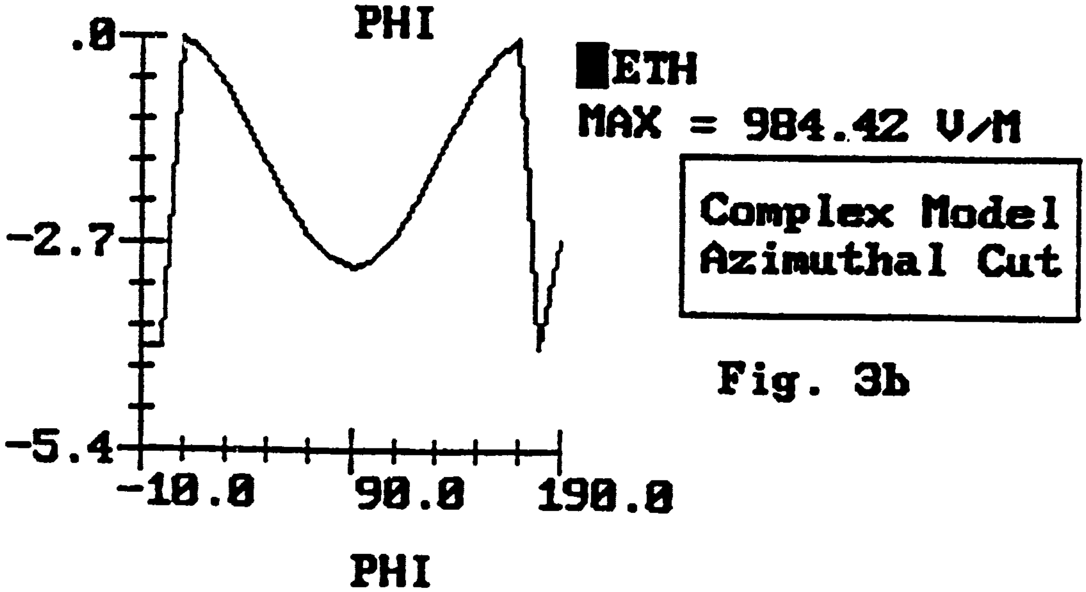
.0
-2.7
-5.4
-10.0
90.0
190.0
PHI
ETH
MAX = 984.42 V/M
Complex Model
Azimuthal Cut

Fig. 3b

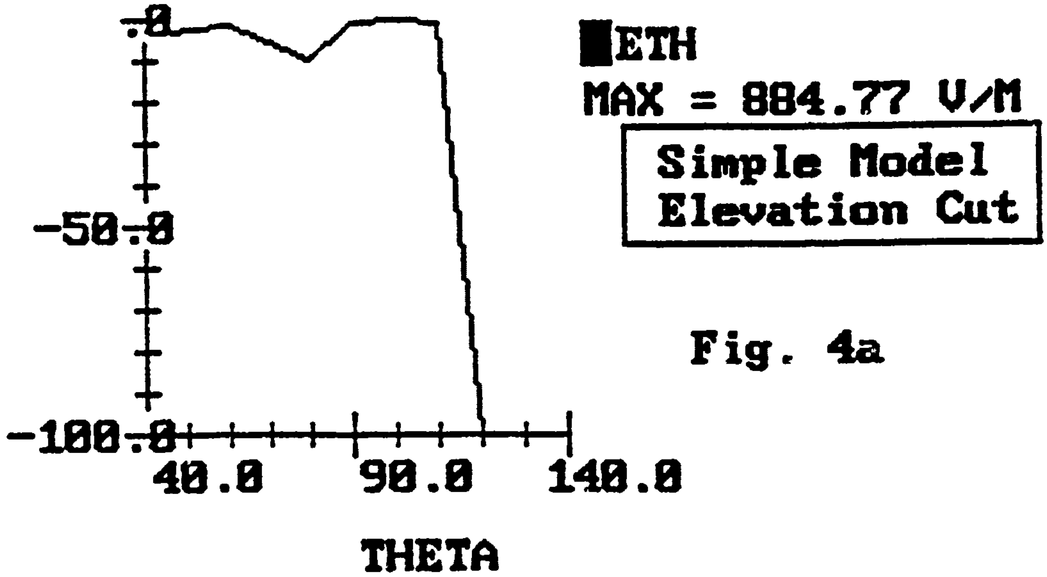
ETH
MAX = 884.77 V/M
Simple Model
Elevation Cut
.0
-50.0
-100.0
40.0
90.0
140.0
THETA

Fig. 4a

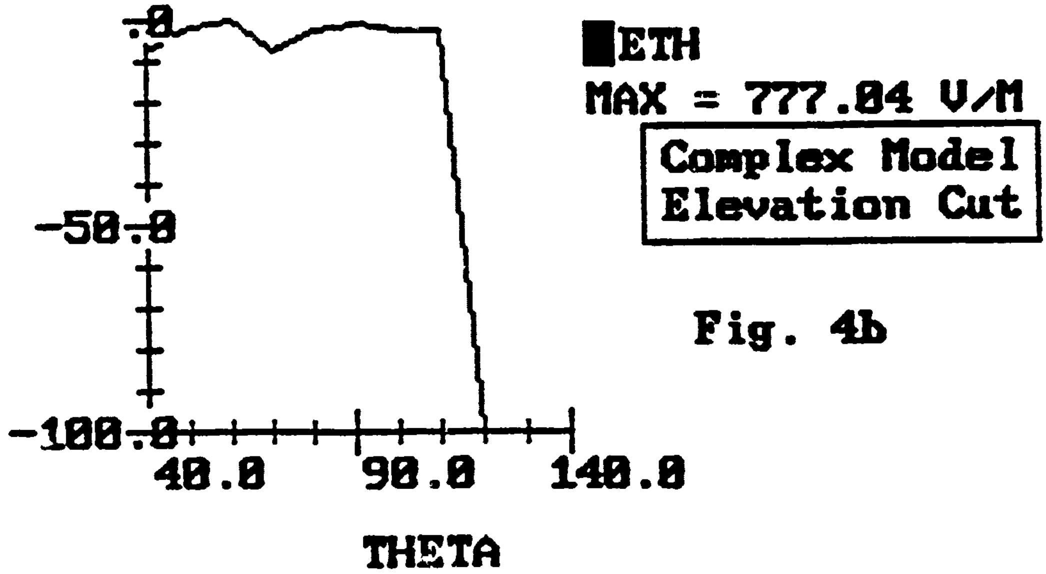
ETH
MAX = 777.04 V/M
Complex Model
Elevation Cut
.0
-50.0
-100.0
40.0
90.0
140.0
THETA

Fig. 4b

results, so the engineer would probably want to use the more complex model. In a case in which more antennas were used, and the whole aircraft was needed, and the runtime went up greatly, then the engineer may want to run a simple model as a scope of the case.

4.0 GEMACS USER SUPPORT

Many problems with computer programs are not foreseen. Reviewing, updating, and editing, play vital parts in the life of a computer program. Such was the case at RBCT upon receiving a message from a GEMACS user in Germany. The message contained a letter explaining the difficulties the user was having, a copy of the input deck of the problem, and a list of errors received upon termination of the test. The user was trying to radiate a dipole over a cylinder, and was getting an arithematic error. The user believed the problem might be a flaw in the copy of GEMACS sent to him, and he requested a new version of the program.

The input deck was analyzed, and there were no apparent errors in the commands. Using the GEMACS User's Manual as a reference, the commands were checked individually for errors, but none were found. Then the case was run through the GEMACS program at RADC/RBCT. The same errors were

given, which meant it was not a problem with the copy that was issued.

The only option left, was to check the geometry of the case. The geometry consisted of a 200 meter cylinder with a radius of 1.625 meters, and a dipole radiating over the center of it at a frequency of 730 MHz. This cylinder seemed rather large, and it became the suspect of the problem. To investigate this further, the cylinder was shortened and the case was rerun. The same errors were received when the case terminated, but the change did seem to have a positive effect, by increasing the runtime of the problem. The cylinder was then made shorter multiple times, until the simulation ran perfectly. The only explanation for this was that the GEMACS program prefers cylinders to have a particular length to radius ratio.

In order to further strengthen this hypothesis, multiple cases were run with cylinders of various length and radius combinations. Upon the completion of these tests it was concluded that the GEMACS program is partial to cylinders that have a lower length to radius ratio than was used in the problem case. The actual length to radius ratio limit was not determined. Suggestions were made on how to overcome this problem, such as connecting multiple smaller cylinders to form the larger one. The explanations

and suggestions were then sent to the user, while the problem was sent to Dr. Coffee for further investigation.

5.0 CONCLUSIONS

Many things were accomplished during the summer apprenticeship. A release version of GEMACS 5.0 was produced. The GEMACS 5.0 code at RADC/RBCT was updated, according to various update releases. Two models of the RC135 aircraft were produced for use at RBCT. During this time the conclusion was reached that the more complex model is worth the extra run time in the case of simple simulations, but the simple model would be good as an overview in more complex cases. Assistance was given to a user of GEMACS in Germany, and in solving his problem, previously unknown limit of the length to radius of a cylinder was discovered. This work was quite significant in that it will have an impact upon users of GEMACS and the work at RADC/RBCT in the coming months. However, the greatest result of the summer was the knowledge gained and the experience that will last a lifetime.

6.0 REFERENCES

1. E.L. Coffey,"GEMACS Version 5, Volume I - User's Manual", Draft Final Report, Advanced Electromagnetics.

2. "VMS Version 5.0 - User's Manual", Digital Equipment Corporation, June 89.

3. A.J. Lockyer, P. Tulyathan, E.L. Coffey, M.J. Grage and G. Upshaw "GAUGE - User's Manual", RADC-TR-88-316, Northrup Corporation, Feb 89.

4. E.L. Coffey, N.W. Coffey and D.L. Kadlec, "GEMACS Source Book ", RADC-TR-88-102, Advanced Electromagnetics, April 88.

UES Apprenticeship Program

Activities at RADC Photnics Lab

Kevin Olson

August 16, 1990

Introduction

During the summer of 1990 I have worked at the Digital Optical Processing division of the Photonics labs at Rome Air Development Center. Photonics is basically the science of using light and lightwave technology to replace the function of electrons. Photonics has several advantages over electronics. Since photons are used, a signal is transmitted at the speed of light, which is much faster than the speed of an electrical transmission. Photonic transmissions can not be "jammed" which is a point of military interest. The goal of the Photonics center is to introduce this new technology to replace existing electrical technology and then to go on to conceive new technological developments using photons in place of electrons.

The following is a brief description of each task and experiment that I worked on during the summer. These tasks were meant to contribute to the Digital Optical Signal Processing division's goal of using photonic technology to replace current electronic digital components.

I. Fiber Optic Measurements

The objective of this project was to calculate the percentage of light reflected at the interface between the end of a bare fiber and air.

Two main types of optical fibers exist: multimode and single-mode. Multimode fiber exhibits multiple modes, a mode being an electric field configuration. Each mode has a different constant velocity. Multiple modes are induced by either the step-index or the graded index properties of multimode fiber. Single-mode fiber propagates only one mode. The core is only 5 to 10 um, compared to the core of multimode fiber being up to 62.5 um. Single mode fiber consists of a glass core surrounded by a cladding with a protective coating surrounding it. A plastic jacket may hold the fiber for additional protection. (See fig. 1) Single mode fiber was used in the project in order to eliminate problems of mode matching.

Several methods were proposed to measure the light reflected from a fiber to air boundary. One procedure used a LED (Light Emitting Diode) as both a detector and receiver. The LED would pulse, sending a light pulse down the fiber. The circuit would then be reconfigured to use the LED as a photodetector and the

light reflected from the end of the fiber could be measured. A detector would be placed at the end of the fiber in order to detect the amount of light being transmitted. (See figs. 2 and 3) A trouble with this proposal was that all of the optics would be free space.

Free space means that the fiber and detectors would not be connectorized. An experiment was preformed to learn about free space setups. One end of a single-mode fiber was mounted on a translation stage, with degrees of movement in three directions. The other end was connectorized and a 1300 nanometer laser signal was sent through the fiber. A photodetector was set up in front of the translation stage. The fiber was moved in each direction until a maximum reading occurred on the photodetector's meter. The experiment showed that free space optical setups for fibers were unstable. The readings on the meter varied greatly with minor movement of the fiber. The translation stage allowed the fiber to move slightly, so a system using free space techniques could get different results due to differences in the amount of light being received by the detector, making the system unreliable.

A second proposal to measure the amount of light reflected off of a fiber facet involved using a fiber optic 'Y' connector. A laser would be hooked up at one side of

the split end of the Y. A detector would be hooked up at the other side of the split. Another detector would be placed on the single end of the connector. The laser pulse would be sent down the fiber. At the point where the three fibers joined, Raleigh-scattering may occur. Raleigh-scattering the the scattering of light due to microscopic changes in the fiber. The back scattering, if any, would have to be measured with the first detector and multiplied by two, since the amount of light backscattered would be evenly split between the fiber connector to the detector and the fiber connected to the laser. The initial laser pulse would continue to travel to the end of the fiber where a percentage of light would be reflected and the rest could be measured by the second detector. The reflected portion of the light would travel back toward the laser and the detector. At the intersection Raleigh-scattering would again occur, which would be measured by the detector at the single end of the Y connector. The reflection could then be measured by the first detector at the split end of the Y connector. (See fig. 4)

The third proposal was to use an OTDR, an Optical Time Domain Reflectometer, to measure reflections. An OTDR is a system which uses either Raleigh-scattering or Fresnal reflections to find faults in fibers. The system works

much like the 'Y' connector setup. The system laser sends a pulse through a two in - two out coupler. The pulse travels through the test fiber, which is hooked up to fiber the laser fiber is being coupled to. The reflection(s) from the pulse are seen by a detector on the same side of the coupler as the test fiber. (See Fig. 5) The OTDR then sends the signal to an oscilloscope. An OTDR is useful for several things. Breaks, fa‹ ‗ts, and connectors in a system can be found. Lengths of fibers and distance between and component of the system can be found. The percentage of light lost at each part of a system can be calculated.

The OTDR was used due to the fact that time would be saved because it was already partially set up, where the other set ups were not yet assembled. The OTDR used was manufactured by Opto-Electronics. Fiber optic patchcords were used to hook the laser and detector to the coupler. The fiber to be used to measure the reflection was assembled. Both fiber ends were stripped and cleaved. Next the fiber was fitted with a ST connector. Both the bare end and the connectorized end of the fiber were ground then polished, first by hand then with an automatic polisher. This process ensures that light is not scattered when entering or leaving the fiber. Index matching fluid, a gel which matches the index of refraction for glass, was put on all of the the connector ends to decrease any

possible reflections, because only the end reflection was wanted.

For the experiment a printer was connected to the OTDR processing unit. The printout was a graph of the pulse along with relative amplitude and FWHM (Full Width Half Maximum) readings. The data was taken from the printout instead of the oscilloscope screen for two reasons: the oscilloscope settings could accidentally become uncalibrated, causing false readings and the printout gave relative amplitude to three decimal places, where the oscilloscope reading would have to be approximated. (See Fig. 6)

First the OTDR system was setup as stated above. (see fig. 5) Two pulses appeared- one from the bulkhead between the coupler and the test fiber connector and the second from the end of the fiber. The first pulse was verified to be the bulkhead pulse by removing the test fiber. The second was checked by bending the fiber at a point very close to the end. Bending a fiber more than a certain amount blocks all light transmission. When the fiber was bent the pulse ended because all light was dispersed.

The pulse from the bulkhead then the end reflection were found. A measurement was taken on each averaging 65536 pulses to get the final results. (fig. 7) The

measurements were repeated in order to ensure the results were accurate. Next the fibers were removed and the laser was hooked directly to the photodetector with a fiber. (fig. 8) The pulse was measured using 65536 averages several times and the results were printed. (fig. 9)

Data:

Pulse	Amplitude 1	Amplitude 2	Average
Bulkhead	0.008	0.008	0.008
End	0.101	0.088	0.095
Laser	2.454	2.439	2.447

The percent of light reflected was found by first subtracting the amplitude of the bulkhead loss from the laser amplitude then dividing the end pulse amplitude by the remaining amplitude and multiplying by one hundred. The following is this calculation:

$$\text{Fiberamp} = \text{Laseramp} - \text{Bulkheadamp}$$
$$= 2.447 - 0.008$$
$$\text{Fiberamp} = 2.439$$

$$\% \text{ reflected} = \frac{\text{Endamp}}{\text{Fiberamp}} \times 100$$

$$= \frac{0.095}{2.439} \times 100$$

$$= 3.9\ \%$$

The accepted value for reflection at a glass-air interface is 4%.

Next the cable length calculations were made. Two five meter patchcords were used in place of the laser and detector fibers. Each cord used in the measurements was then setup where the test cord had been. The bulkhead and end pulses were measured and the time delay and reference was recorded for each. The graphs were printed. The time quantity of the graph, the x axis, starts at zero for all graphs. To calculate the actual time of the pulse, the time of the peak on the graph had to be added to the time delay and reference values*. (fig. 10) The formula

$$L = \frac{ct}{2n}$$

where L is the length, c is the speed of light, 3.0 x 10 cm/s, t is the time between the bulkhead end end pulses, and n is the absolute index of refraction could be used to find the value of nL, since the index of refraction was not known.

Data:

Time is in Nanoseconds

Cable	Bulkhead Graph time	Bulkhead delay	Bulkhead total	End Graph time	End Delay	End total
Laser	1.06	182.8	183.86	1.06	194.8	195.86
Detector	1.12	182.8	183.92	1.09	194.8	195.89
Test	1.08	182.8	183.86	1.02	233.3	234.32

Time differences between bulkheads and ends:

$$
\begin{aligned}
\text{Lasertimdif} &= \text{Laserendtim} - \text{Laserbulktim} \\
&= 195.9 \text{ ns} - 183.9 \text{ ns} \\
&= 12 \text{ ns} \\
\text{Detecttimdif} &= \text{Detectendtim} - \text{Detectbulktim} \\
&= 195.9 \text{ ns} - 183.9 \text{ ns} \\
&= 12 \text{ ns} \\
\text{Testtimdif} &= \text{Testendtim} - \text{Testbulktim} \\
&= 234.3\text{ns} - 183.9 \text{ ns} \\
&= 50.4 \text{ ns}
\end{aligned}
$$

Calculations for nL where t = the time difference for each fiber:

$$nL = \frac{ct}{2}$$

Laser fiber:

$$nL = \frac{3.0 \times 10 \text{ cm/s} \times 1.2 \times 10^{-9} \text{ s}}{2}$$

$$nL = 18^{\wedge} \text{ cm}$$

Detector fiber:

$$nL = \frac{3 \times 10 \text{ cm/s} \times 1.2 \times 10^{-9} \text{ s}}{2}$$

$$nL = 180 \text{ cm}$$

Test fiber:

$$nL = \frac{3 \times 10 \text{ cm/s} \times 5.04 \times 10^{-9} \text{ s}}{2}$$

$$nL = 756 \text{ cm}$$

The length of the laser fiber was physically measured in order to calculate the absolute index of refraction for the fiber. The measured length was 123 cm.

$$nL = 180 \text{ cm}$$

$$L = 123 \text{ cm}$$

$$n = \frac{180 \text{ cm}}{123 \text{ cm}}$$

$$n = 1.46$$

Length values for the detector and test fibers were then calculated using the value for the index of refraction, giving a detector fiber length of 123 cm and a

test fiber length of 518 cm.

An OTDR proved to be a useful and effective apparatus for calculating fiber measurements. It is rather complicated to learn and use, but its results are worth the effort. The goal of measuring the reflection at a fiber end was reached due to the OTDR.

II. Detectors

Several types of photodetectors exist. Some examples are cad sulphide, solar cells, photomultiplyer tubes, and PIN diodes. PIN diodes possess several characteristics which make them preferable to the other types of detectors. PIN diodes are linear. The sensitivity is directly proportional to the surface area. The tradeoff is that the speed is inversely proportional to the area. Another advantages are that PIN diodes are solid state, they are stable, and bandwidth.

A relationship, current is equal to a constant times the intensity, exists for PIN diodes.

The relationship is: $J=kI$ where $J=$ current $I=$ intensity and k is dependent on wavelength.

The constant k differs for each photodetector and each surface area. An experiment was set up to find this constant for a photodetector that was to be used in an anti-reflective coating system. A 630 nm He-Ne laser beam was sent through a neutral density filter then detected with the PIN diode. The neutral density filter decreased the laser output by a factor of 10 raised to the optical density of the filter.

$$\text{Intensity out} = \text{intensity in} \times 10^{-OD}$$

$$I_o = I_i \; 10^{-OD}$$

Neutral density filters ranging from 0.1 to 1.5 were

used. The PIN diode circuit was configured to measure voltage, so the relationship

$$J=\frac{V}{R}$$

was used. A resistance of 5.1 K was used in the circuit. (fig. 10) The following is a table of the values of the optical density for each neutral density filter used, the resulting voltage, and the calculated current.

OD	Voltage	Current
0.0	10.43	2.05
0.1	10.40	2.04
0.3	7.04	1.38
0.4	5.93	1.16
0.5	4.62	0.91
0.8	2.12	0.43
1.0	1.41	0.28
1.5	0.43	0.09

The power rating of the laser was 6.4 mw, which was checked with an optical power meter. From this the intensity of the beam could be calculated using the formula

$$\text{intensity} = \frac{\text{laser power} \times 10^{-OD}}{\text{surface area of detector}}$$

The radius of the detector was measured to be .15 cm, therefore the area was calculated as .071 square centimeters.

The following is a list of the optical densities and the corresponding intensity values.

OD	Intensity (mw/cm)
0.0	91.0
0.1	72.3
0.3	45.6
0.4	36.2
0.5	28.8
0.8	14.4
1.0	9.1
1.5	2.9

The values of intensity versus current were graphed and k was calculated using the slope as 0.03. (fig. 11)

III. Mathematica

Mathematica is a computer package designed to do mathematical computations. Mathematica can preform simple calculations, solve algebraic equations and compute and display graphics in two or three dimensional plots.

The equation Csc [2(x+yz)] - z = 0 needed to be graphed in three space for an Acousto-optical switch technical paper. The equation is the derivative of an equation which determines the properties of the switch.

The equation first had to be put in terms of one variable being a function of the other two. Y and z could not be isolated, leaving x. The following is the solution:

$$\mathrm{Csc}[\,2(x+yz)\,] - z = 0$$

$$\mathrm{Csc}[\,2(x+yz)\,] = z$$

$$2\,(x+yz) = \mathrm{ArcCsc}[z]$$

$$x+yz = \frac{\mathrm{ArcCsc}[z]}{2}$$

$$x = \frac{\mathrm{ArcCsc}[z]}{2} - yz$$

Next the equation had to be put into Mathematica format for the program to accept the equation and plot it.

```
Plot3D [ (ArcCsc[z]/2) - y z,{y,-10,10},{z,-10,10}]
```

Plot3D requests the program to plot the equation as a three dimensional graph. The first and last brackets

enclose what is to be plotted. The space between the y and the z tells Mathematica to multiply the variables. The ranges of y and z are given by {y,-10,10} and {z,-10,10}. This statement tells Mathematica to plot the graph for all y values between negative ten and positive ten and all z values between negative ten and positive ten. Figure 12 is the resultant graph of the equation.

The next set of equations to be graphed were $y = \sin^2(x+zy)$. Set values were given for z- 1, 2 and 3- so the graph was plotted in two dimensional graphics. Again the equation had to be solved for x, giving x = ArcSin (y)-zy. The Mathematica format was: Plot [ArcSin[Sqrt[y]] - zy,{y,0,10}]. The values of one to three were put in and each was graphed separately. (fig. 13) These equations showed the properties of the acousto-optic switch.

IV. Digital Electronics

An important part of the experience was learning digital electronics. Simple experiments were preformed using a Radio Shack experiment kit that was altered for a college level physics class. LED's, capacitors, photo resistors, and transistors were studied for these simple setups.

Next transistors were studied at a more advanced level. Circuits were built that used transistors as switches and amplifiers. The various logic gates, and, or, nor, inverse, etc, were build using transistor logic. Finall TTL logic was studied, reading and building circuits with the various TTL integrated circuits.

Using experience from the PIN diode experiments and digital experiments, an opto-electic memory circuit was designed and built. (fig. 14) The memory is turned to the "on" state when the first photodetector (labled 1) is exposed to light. When the diode is activated, current is allowed to flow through the transistor, causing the LED to light. The light from the LED keeps the PIN diode active, creating a feedback loop. The memory is turned "off" when the PIN diode marked 2 is exposed to light. When current is allowed to flow through the second PIN diode the

transistor is "robbed" of its current, causing the LED, and therefore the feeback loop to turn off.

Knowledge of digital logic contributed to all experiments and projects.

V. Miscellaneous

Along with the PIN diode calibration, a light source was needed for the AR (anti-reflective) coating system. A housing for the light source was custom designed and machined. The housing enclosed a white light bulb, a bulb holder, and a fan to cool the light so that heat expansion would not affect the AR coating system preformance. (fig. 15) Later it was found that the bulb had to be replaced with a different type since the original bulb focused down to a circle, not a point. Another problem was that the bulb had to give off light with a greater intensity for the system to work.

A second project was transposing hand-drawn figures to a computer drawing program. (fig. 16) These figures were for another technical document. They involved learning to use a computer package and learning the background of the paper and technical information.

Acknowledgements:

I would like to thank Universal Energy Systems for sponsoring the Summer High School Apprenticeship Program and all of the staff at Rome Air Development Center in the Photonics Lab who have been very helpful during my apprenticeship. I would like to extend my deepest appreciation to Mike Parker, my mentor. He has been a great teacher and friend.

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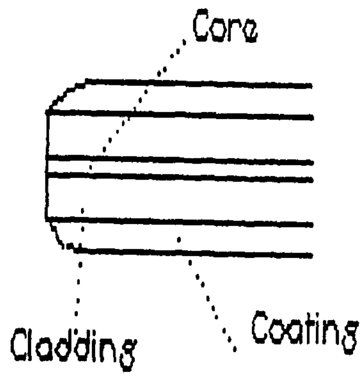


Figure 1: Diagram of a Single-Mode Fiber

Figure 1: Diagram of Single Mode Fiber construction

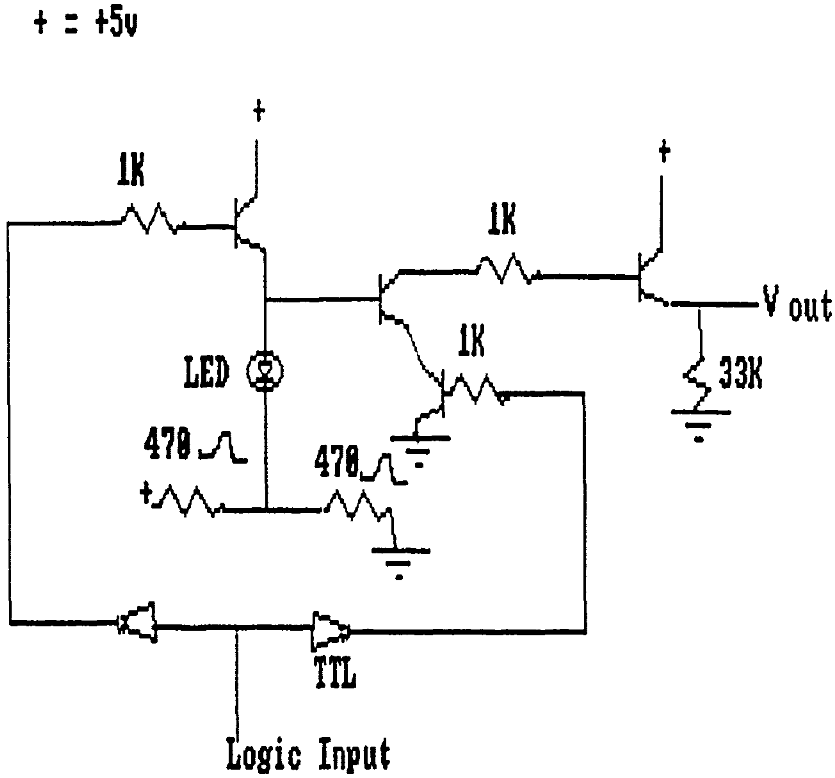
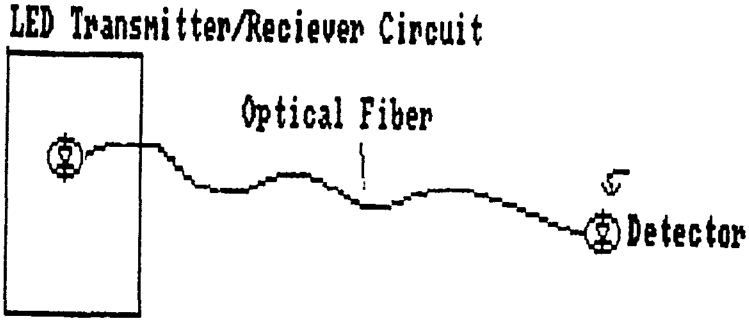


Figure 2: LED transmitter/reciever cirCuit diagram



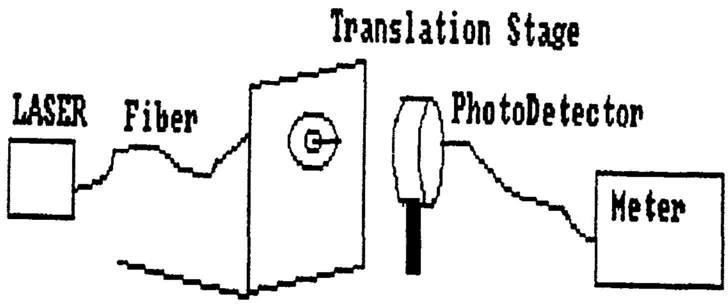


Figure 3: LED transmitter set up with example of Free space optical detection

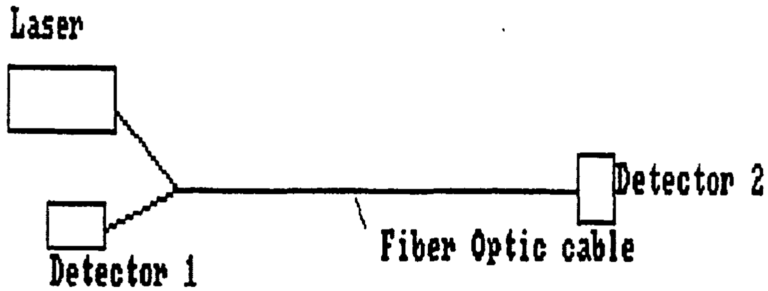


Figure 4 : Y adapter model for determination of reflection

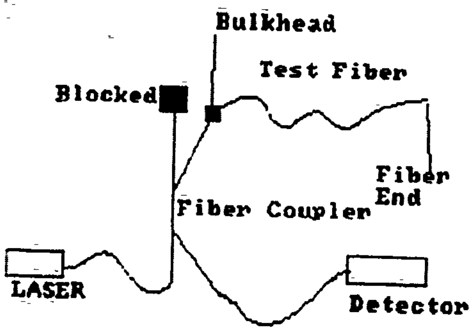


Figure 5: OTDR optical coupler setup

Ref Retain
Times

Δ S.U. Knob 200-3
series

Figure 6: OTDR printout example

200
-4
vert
scal/loss
ON

OPTO-ELECTRONICS INC.

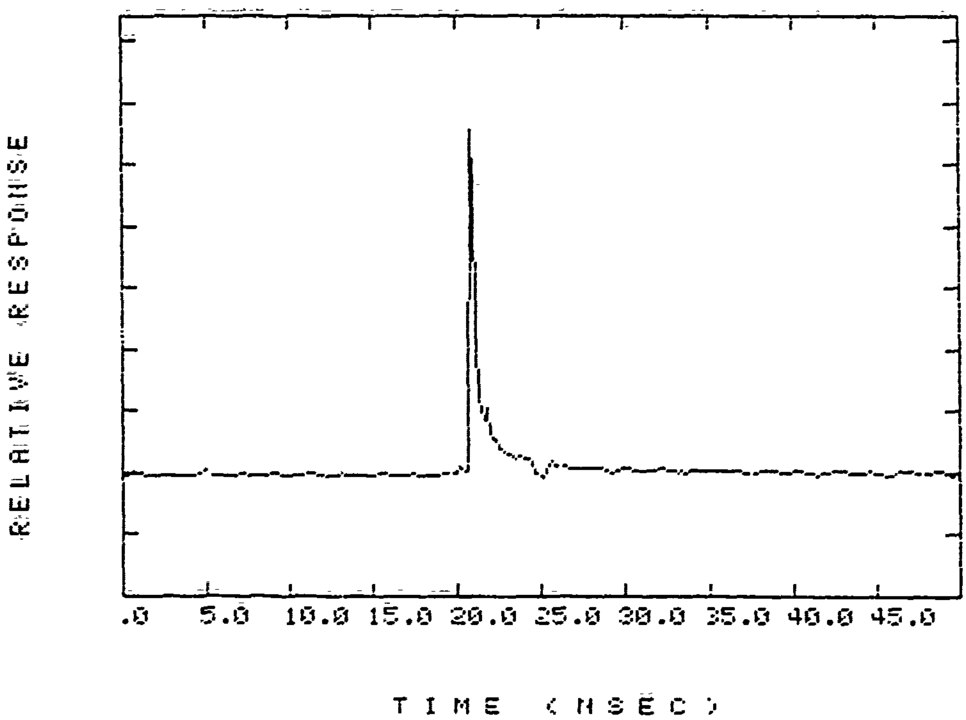
DATE:------------------

FIBER TYPE:------------- LENGTH:------------ (KM)

LOT #:------------------ INSPECTOR:--------------

FWHM: 01.6 NSEC MODE: MEASURE

AMPLITUDE(S): -.374



TDR20

OPTO ELECTRONICS INC.

2.00

Bulkhead
200 SU
65536
-64
143.50
-5T

Figure 7.0 - Reflection Measurements (3

OPTO-ELECTRONICS INC.

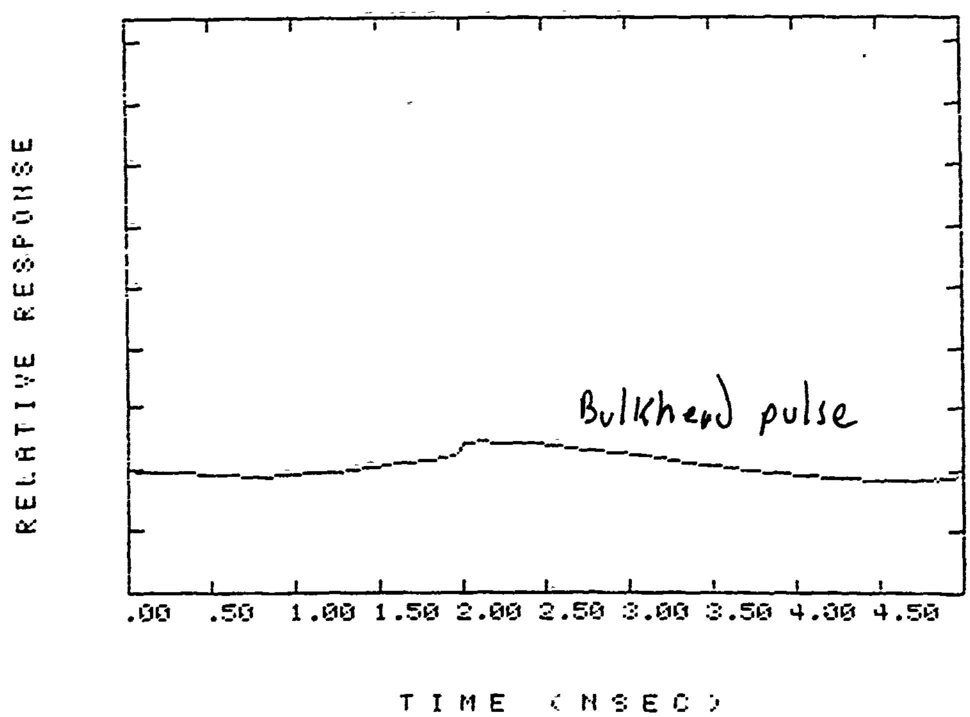
DATE:-------------------

FIBER TYPE:------------- LENGTH:------------ (KM)

LOT #:------------------ INSPECTOR:--------------

FWHM: ??? NSEC MODE: MEASURE

AMPLITUDE(S): -.008



TDR20
OPTO ELECTRONICS INC.

2.00
.33

.5 T
50
65536
-32

Figure 7.1: Reflection

OPTO-ELECTRONICS INC.

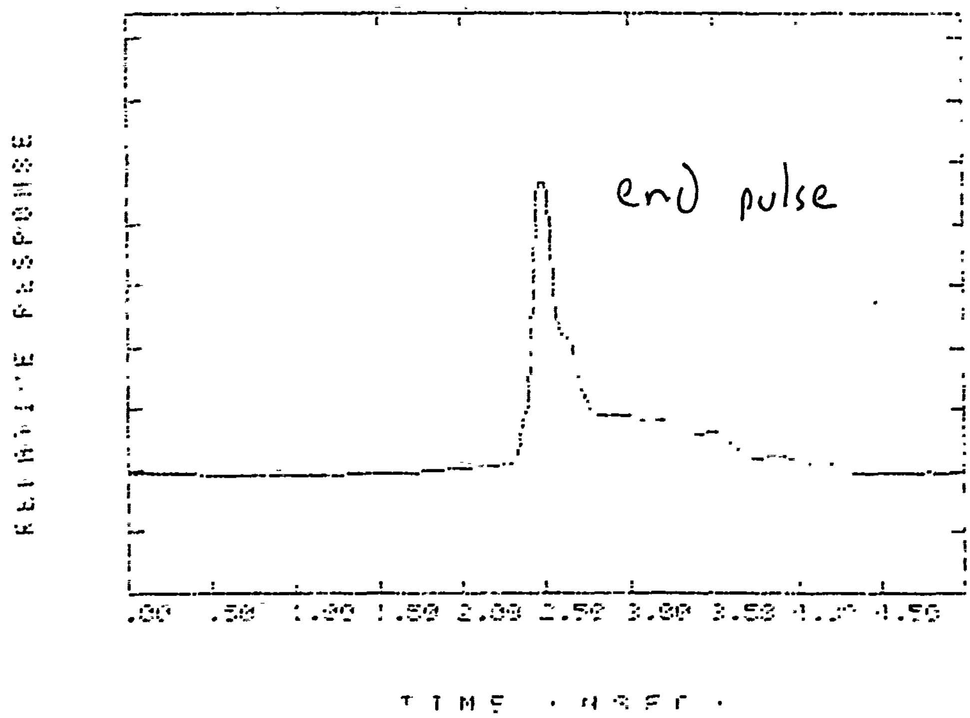
DATE:

FIBER TYPE: LENGTH:

LOT #:   INSPECTOR:

FWHM: .2? NSEC   MODE: MEASURE

AMPLITUDE(S): .101



TDR20
OPTO ELECTRONICS INC.

3.4

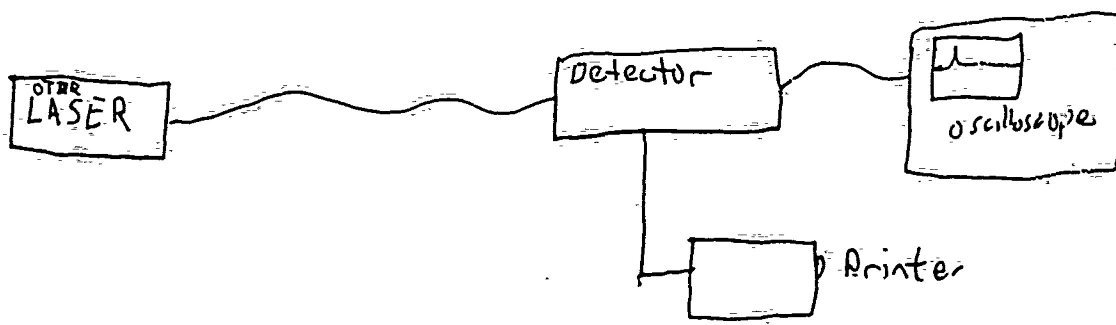


Figure 8: Laser to detector direct setup

laser
200 SU 1.5 T
65536
200 SU
-1
120.5 % r 3

OPTO-ELECTRONICS INC.

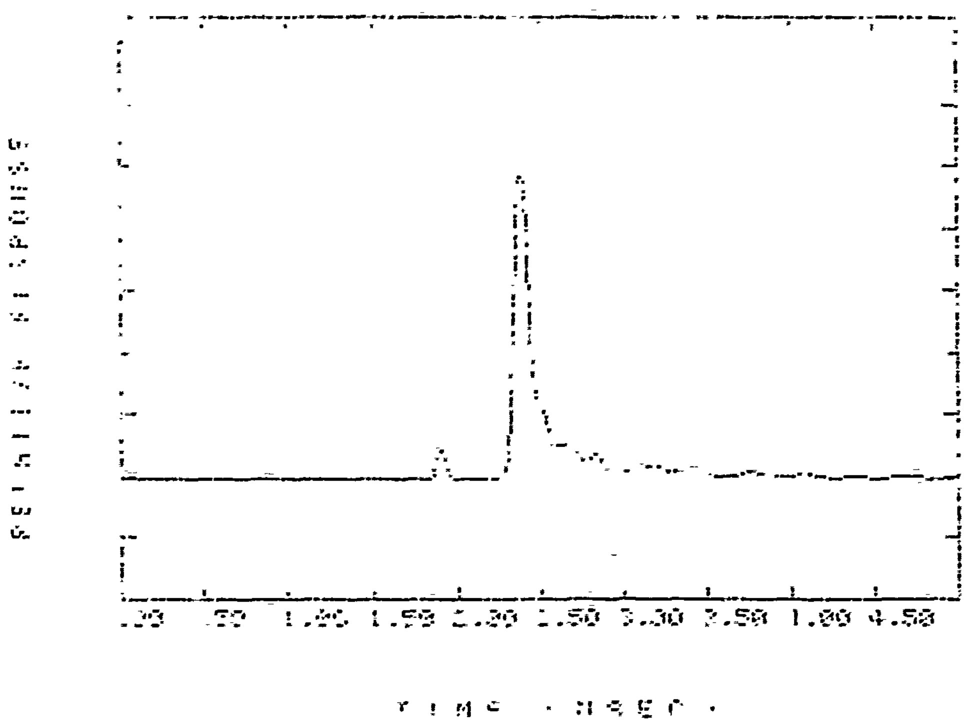
DATE:

FIBER TYPE: LENGTH: (km)

LOT #: INSPECTOR:

RANGE: 0.15 NSEC MODE: MEASURE

AMPLITUDE: -2.488



TDF20
OPTO ELECTRONICS INC.

Figure 9: Direct laser Pulse

Bulkhead cable

length

Figure 10.0: - length graphs

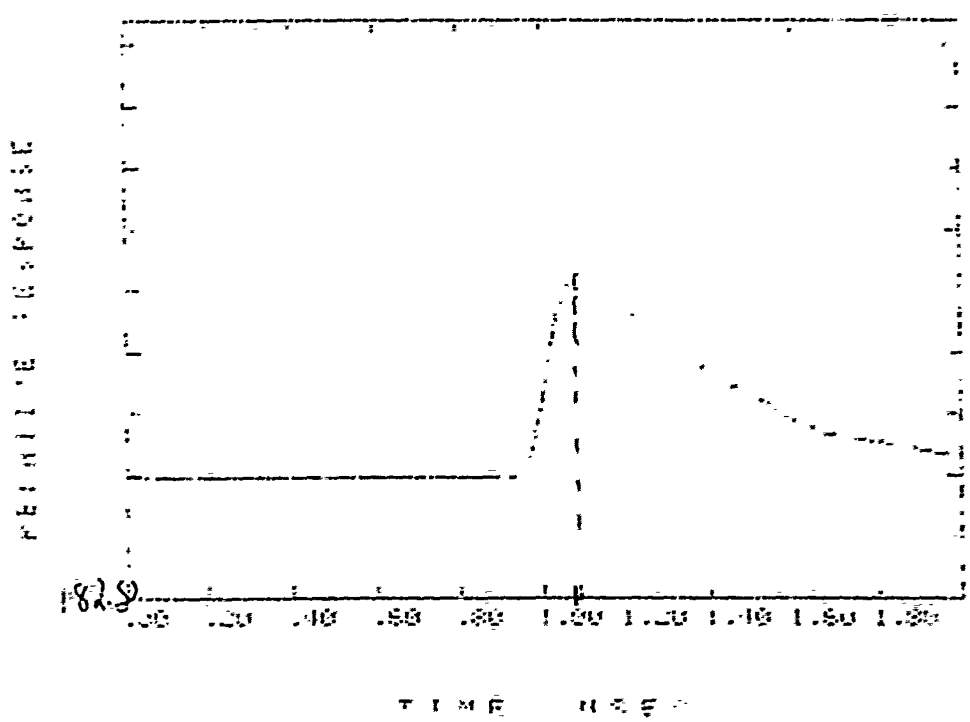
DATE: ----------------------

FIBER TYPE: ---------------- LENGTH: ---------------

UNIT #: -------------------- INSPECTOR: -------------

SPAN: 0.41 NSEC MODE: MEASURE

AMPLITUDE: -.211



$182.8 + 1.08 = 183.88$

end
T. cable

length

Figure 10.1: length

OPTO-ELECTRONICS INC.

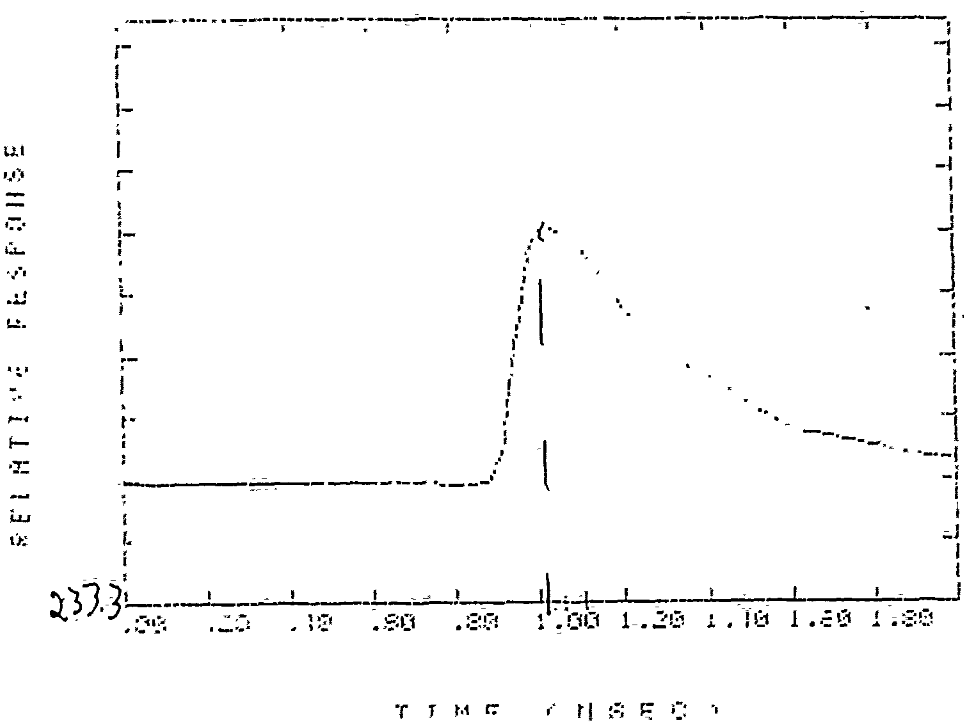
DATE:------------------

FIBER TYPE:------------ LENGTH:------------ KM.

LOT #:---------------- INSPECTOR:-------------

FWHM: [illegible] NSEC MODE: MEASURE

AMPLITUDE(V): [illegible]



TORCO
OPTO ELECTRONICS INC.

$233.3 + 1.02 = 234.32$

Bulkhead
Detector

length

Figure 102: length

OPTO-ELECTRONICS INC.

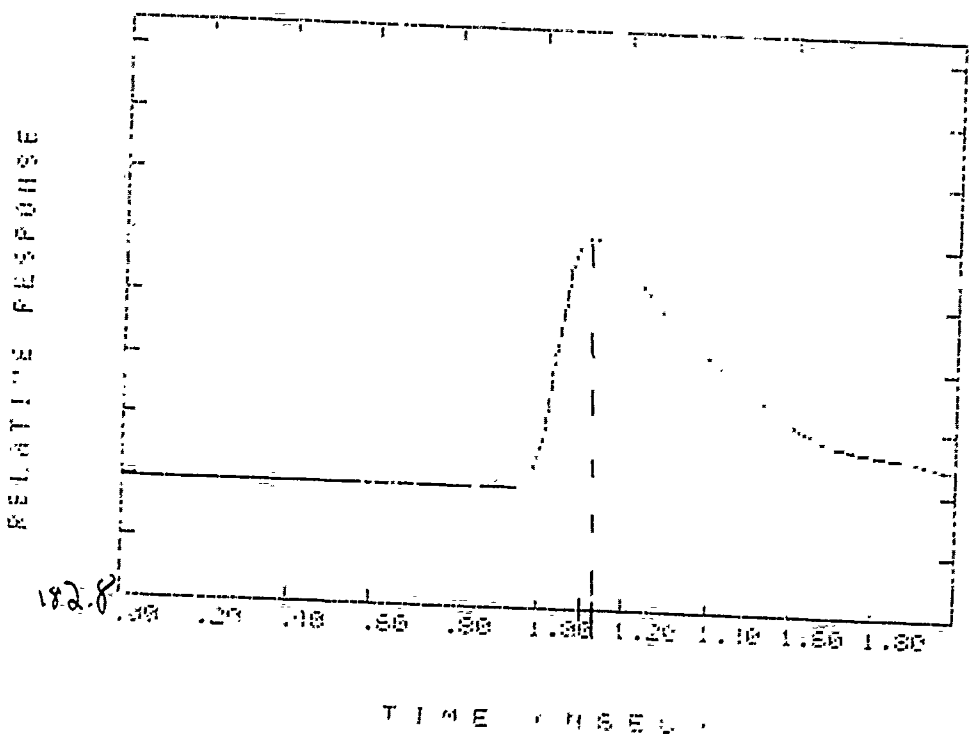
DATE:

FIBER TYPE: LENGTH: (FM)

LOT #: INSPECTOR:

FWHM: 0.28 NSEC MODE: EXPOSURE

AMPLITUDE(E): -.261



TOP20

OPTO ELECTRONICS INC.

2.00

182.8 + 1.12 = 183.92

end
detector

Figure 10.3: length

OPTO-ELECTRONICS INC.

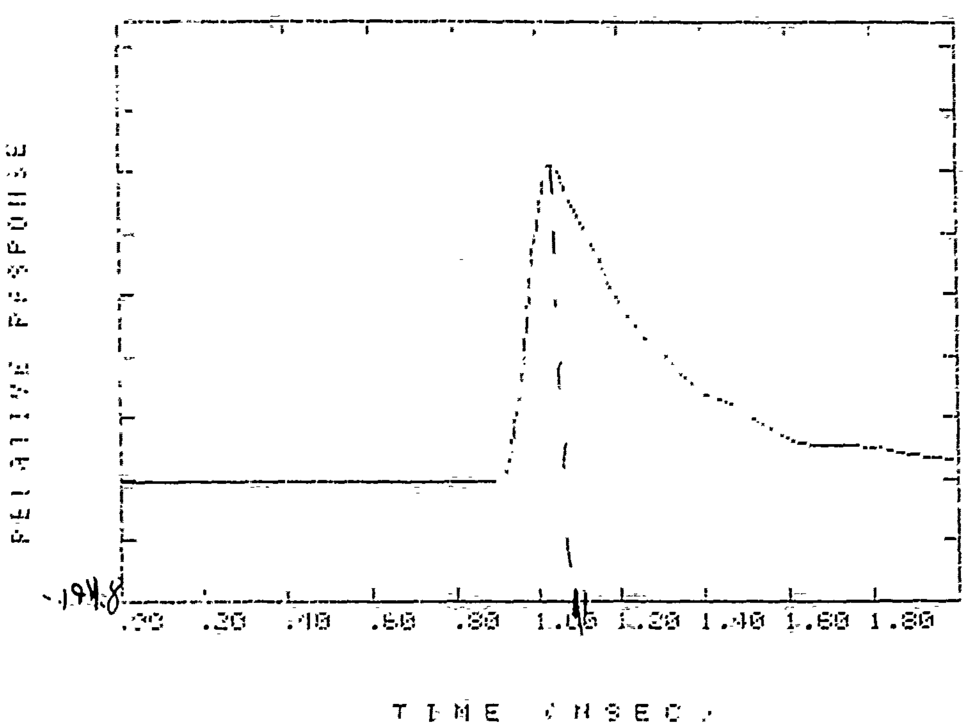
DATE:

FIBER TYPE: LENGTH: (KM)

LOT #: INSPECTOR:

FWHM: 0.27 NSEC MODE: MEASURE

AMPLITUDE(V): -1.278



TDR20
OPTO ELECTRONICS INC.

2.00

194.8 + 1.08 = 195.88

Bill (new) user fiber

length

Figure 10.4 length

OPTO-ELECTRONICS INC.

DATE:

FIBER TYPE:

LENGTH: (M)

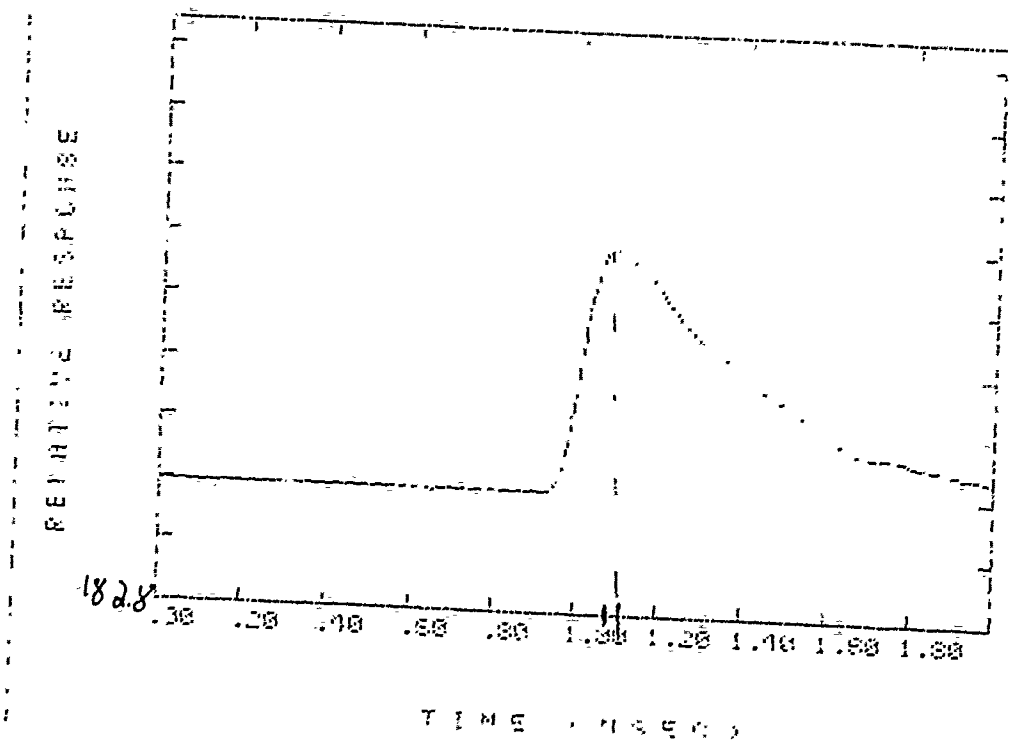
LOT #:

INSPECTOR:

FWHM: 3.40 NSEC

MODE: MEASURE

AMPLITUDE(%): -.251



TDR20

OPTO ELECTRONICS INC.

2.00

182.8 + 1.06 = 183.86

2nd laser

length

Figure 10.5: length

OPTO-ELECTRONICS INC.

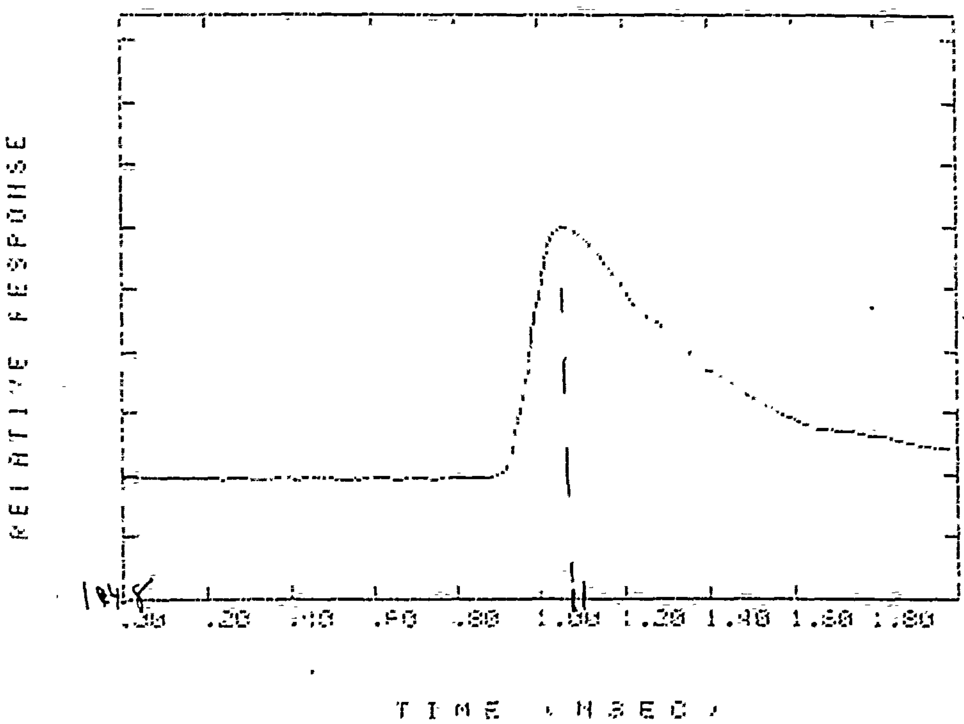
DATE:--------------------

FIBER TYPE:-------------- LENGTH:------------ (KM)

LOT #:------------------- INSPECTOR:-------------

FWHM: 0.17 NSEC MODE: MEASURE

AMPLITUDE (V): -.250



TORIO

OPTO ELECTRONICS INC.

2.00

104.8+1.06= 105.86

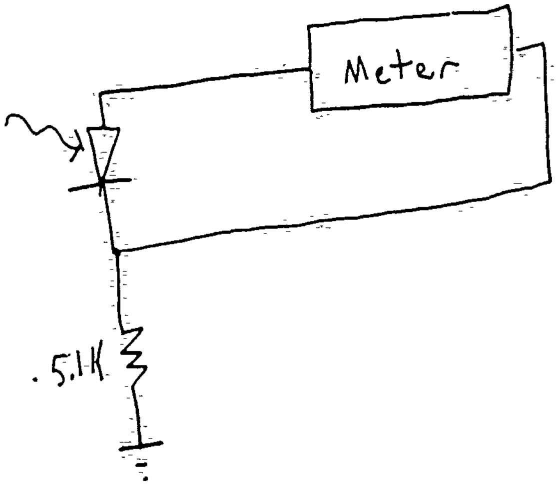
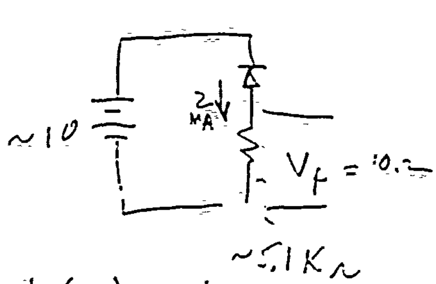
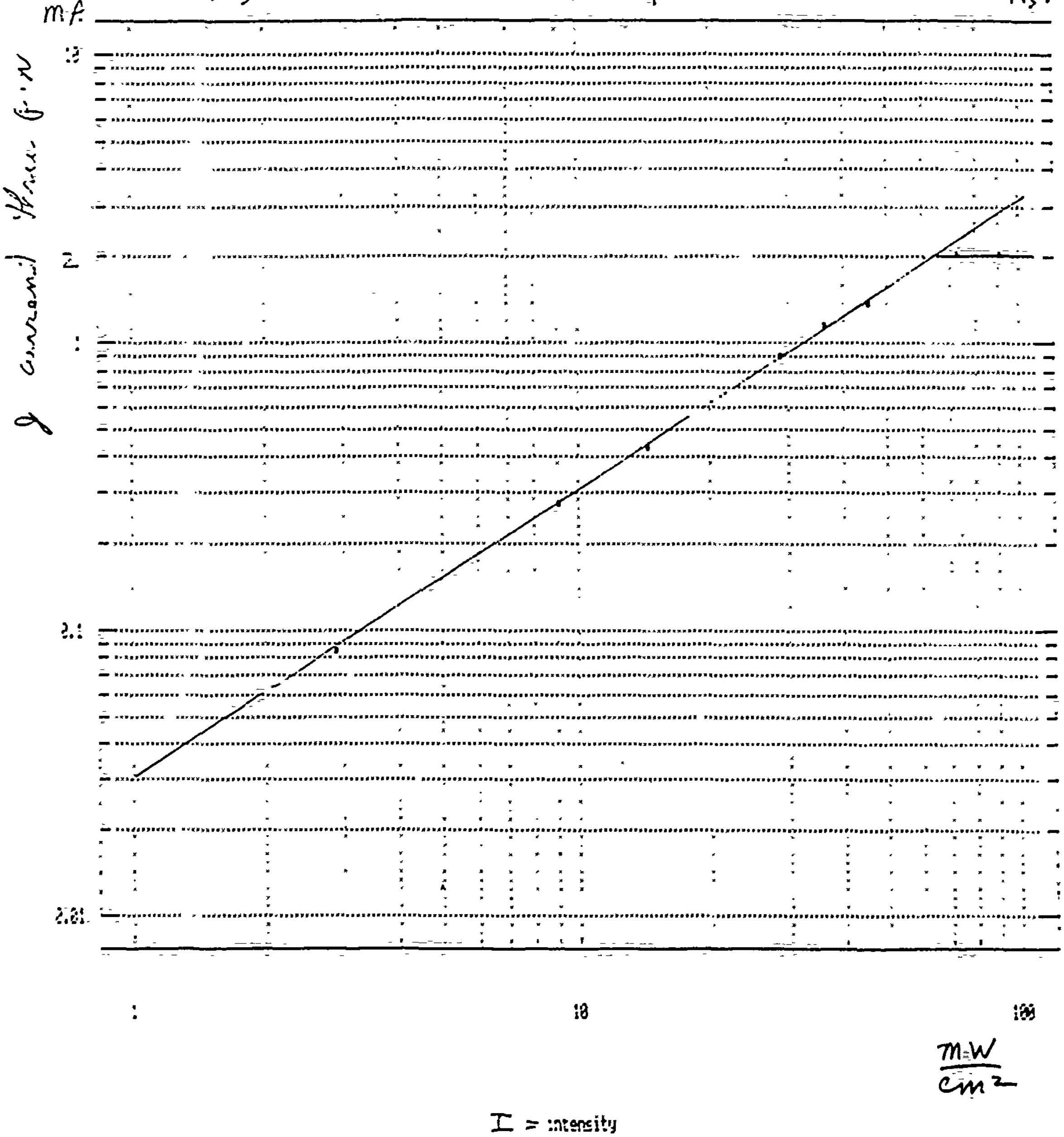


Figure 11: PIN Diode circuit



Plot of ip vs intensity

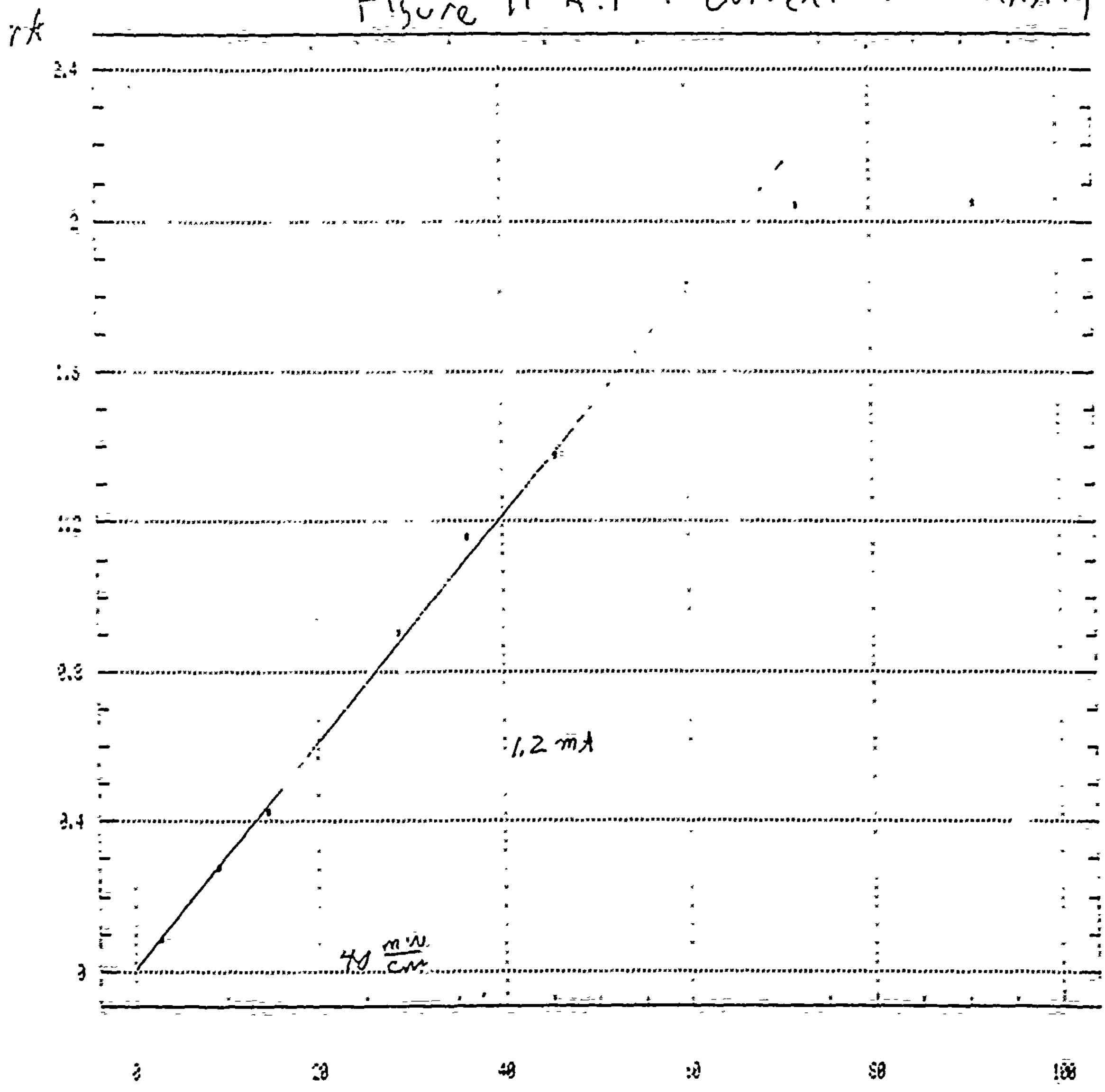
Figure 11 A.1: Graph of current (IP) vs intensity



$$J = k(\lambda)\, I$$

Plot of ip vs intensity

Figure II A.1 . current vs intensity for PIN Diode



$\boxed{j = k(\lambda) I = 0.03 I}$

$k \sim \frac{i}{i_0}$

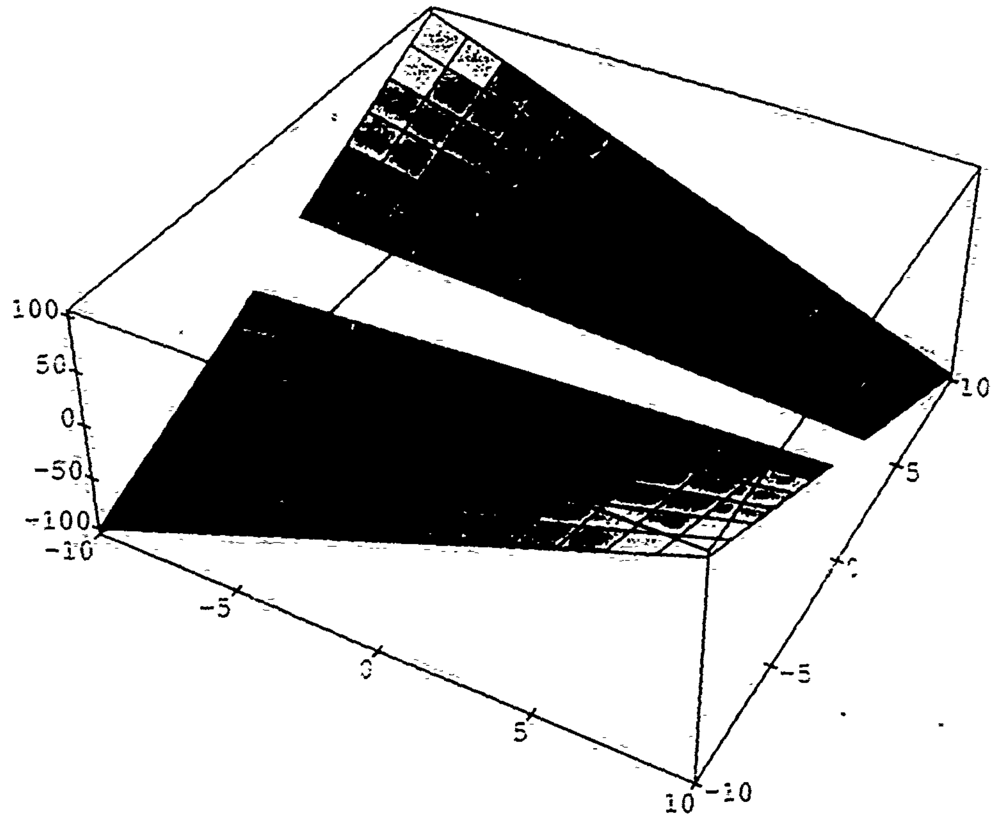


Figure 12: $\csc[2(x+yz)]-z=0$
Mathematica plot

$x = $ [illegible] $- 2y$

$z = $ [illegible]

In[14]:=

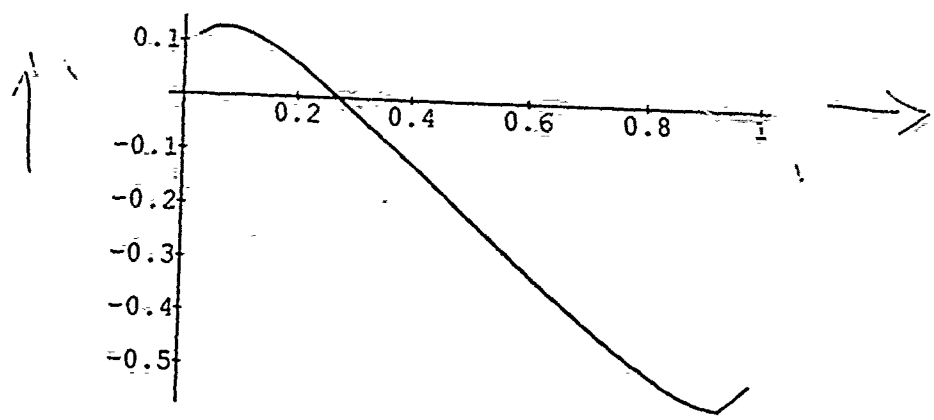
```
Plot[ArcSin[Sqrt[y]]- 2 y,{y,-10,10}]

Plot::notnum:
   ArcSin[Sqrt[y]] - 2 y does not evaluate to a real number at y
    =-10..

Plot::notnum:
   ArcSin[Sqrt[y]] - 2 y does not evaluate to a real number at y
    =-9.16667.

Plot::notnum:
   ArcSin[Sqrt[y]] - 2 y does not evaluate to a real number at y
    =-8.33333.

General::stop:
   Further output of Plot::notnum
     will be suppressed during this calculation.
```



Out[14]=

```
-Graphics-
```

Figure 13.10: $y = \sin(x + 2y)$ where $z = 1$

In[16]:=

```
Plot[ArcSin[Sqrt[y]]- 3 y,{y,-10,10}]
```

```
Plot::notnum:
   ArcSin[Sqrt[y]] - 3 y does not evaluate to a real number at y
    =-10..

Plot::notnum:
   ArcSin[Sqrt[y]] - 3 y does not evaluate to a real number at y
    =-9.16667.

Plot::notnum:
   ArcSin[Sqrt[y]] - 3 y does not evaluate to a real number at y
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General::stop:
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     will be suppressed during this calculation.
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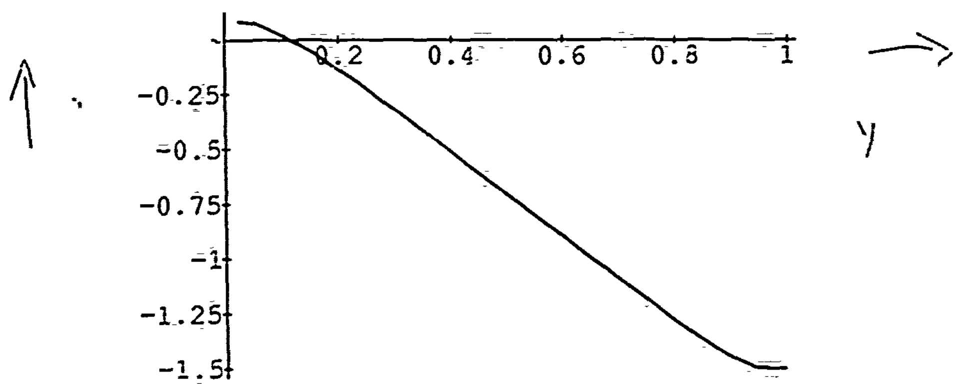


Out[16]=

-Graphics-

Figure 13.1: $y = \sin(x + 2y)$

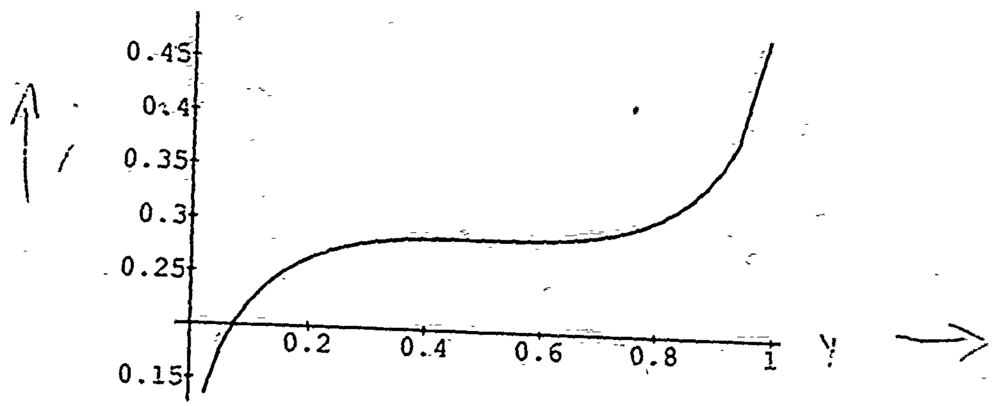
 $\sin^{-1}\sqrt{y} - \beta y$

$x = \sin^{-1}\sqrt{y} - z$

$z = 1$

In[13]:=

```
Plot[ArcSin[Sqrt[y]]-y,{y,-10,10}]
Plot::notnum:
   ArcSin[Sqrt[y]] - y does not evaluate to a real number at y=
    -10..
Plot::notnum:
   ArcSin[Sqrt[y]] - y does not evaluate to a real number at y=
    -9.16667.
Plot::notnum:
   ArcSin[Sqrt[y]] - y does not evaluate to a real number at y=
    -8.33333.
General::stop:
   Further output of Plot::notnum
     will be suppressed during this calculation.
```



Out[13]=

```
-Graphics-
```

$y = \sin^2(x+\beta y)$

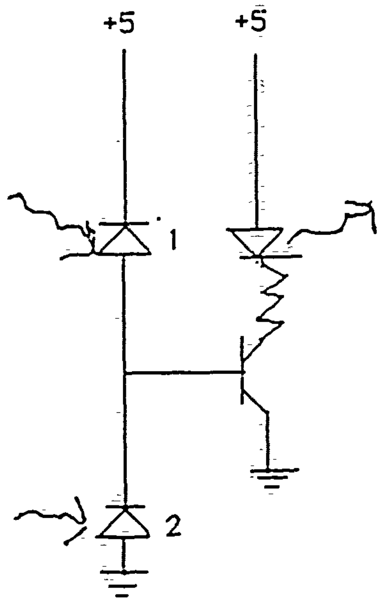
$\sqrt{y} = \pm \sin(x+\beta y)$

$\arcsin\sqrt{y} = \pm(x+\beta y)$

$x = \arcsin\sqrt{y} - \beta y$

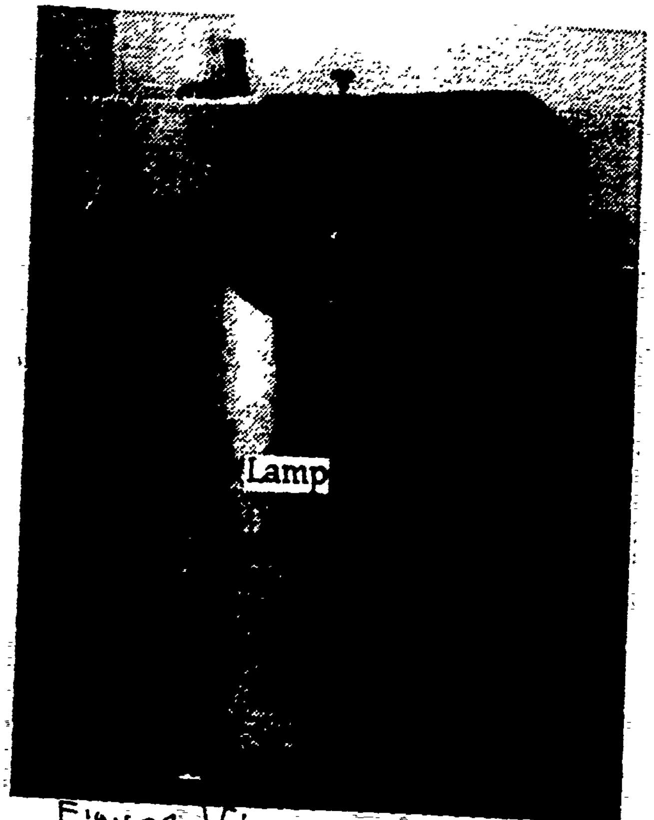
or $x = \beta y - \arcsin\sqrt{y}$

Figure 13.2: $y = \sin(x+\beta y)$



The memory is turned on when the PIN dioide marked 1 is exposed to light.. When the diode is activated current is allowed to flow through the transistor, causing the LED to light. The light from the LED keeps the PIN diode active, creating a feedback loop. The memory is turned off when the PIN diode marked 2 is exposed to light. When current is allowed to flow through the second pin diode the transistor is "robbed" of its current, causing the LED, and therefore the feedback loop to turn off.

Figure 14: Electro-optic memory



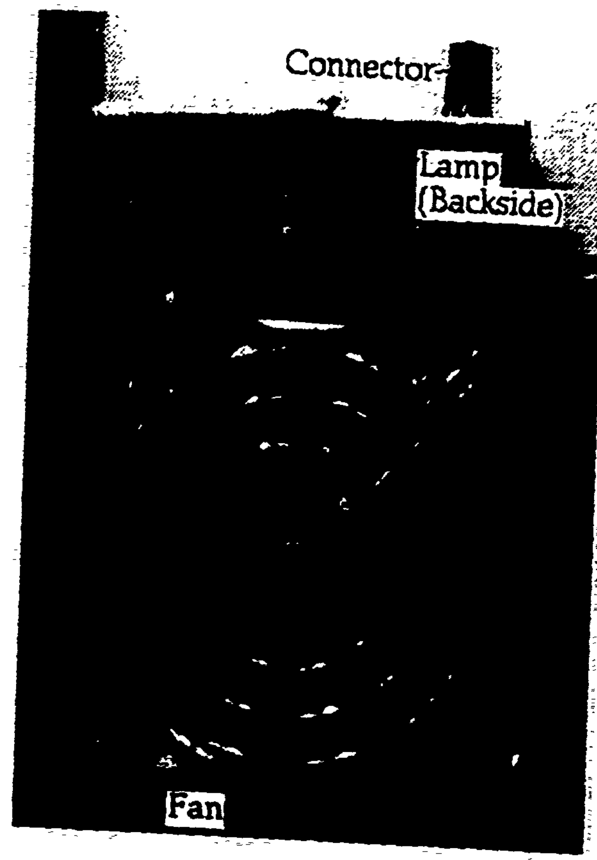


Figure 15:
Lamp Box
to be used in the AR coating system.

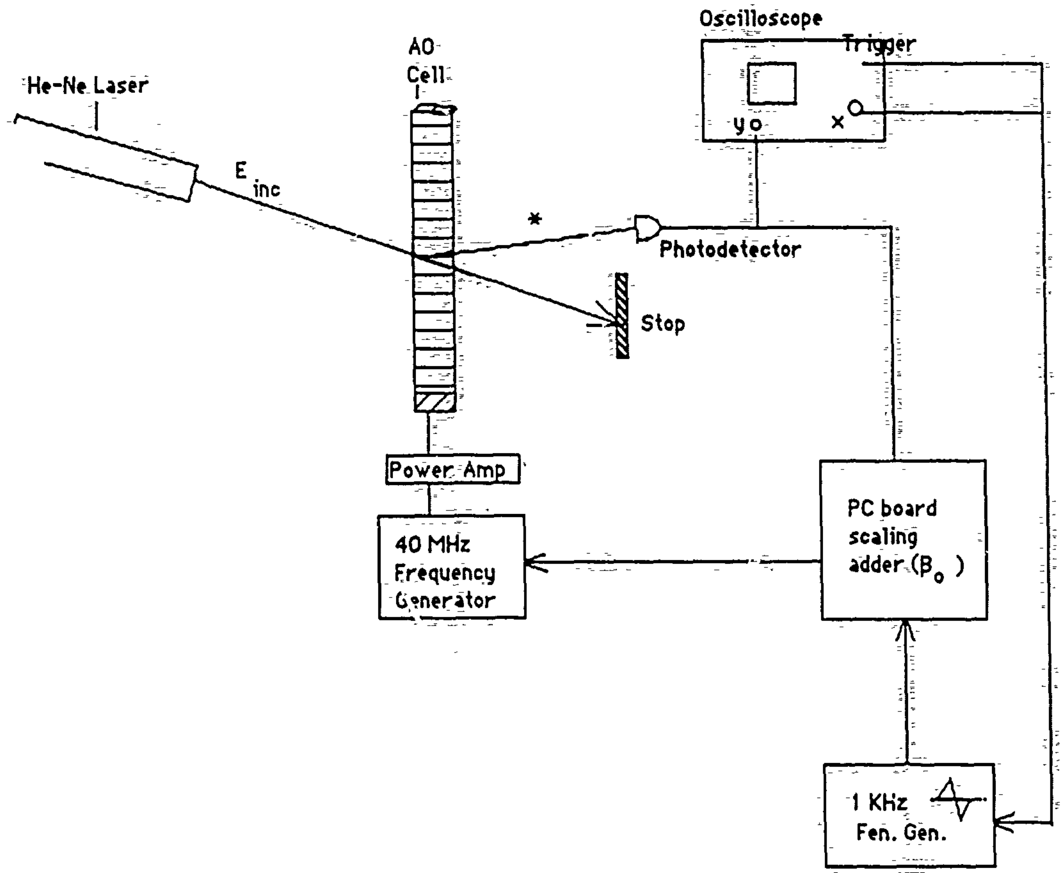
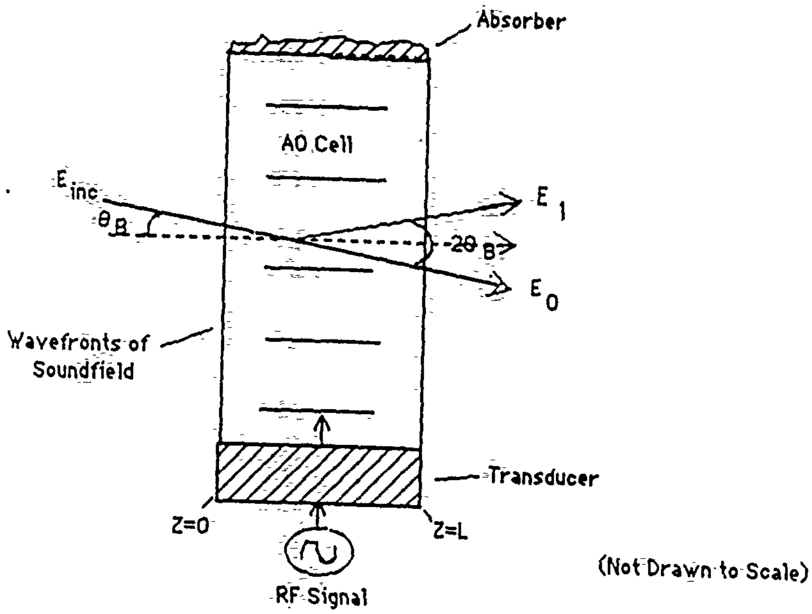


Figure 3: Experimental Set-Up (Modified Set-Up for Incremental α_0)

(*: It was necessary to insert a 0.5 optical density filter here.)

Figure 16.0 : Computer drawings



Constructive Interference occurs for $\sin\theta_B = \frac{\lambda}{2\Lambda}$

where λ = the wavelength of light

Λ = the wavelength of sound

Figure 1: Basic Principles of AO Operation

Figure 16.1 : Tech drawings

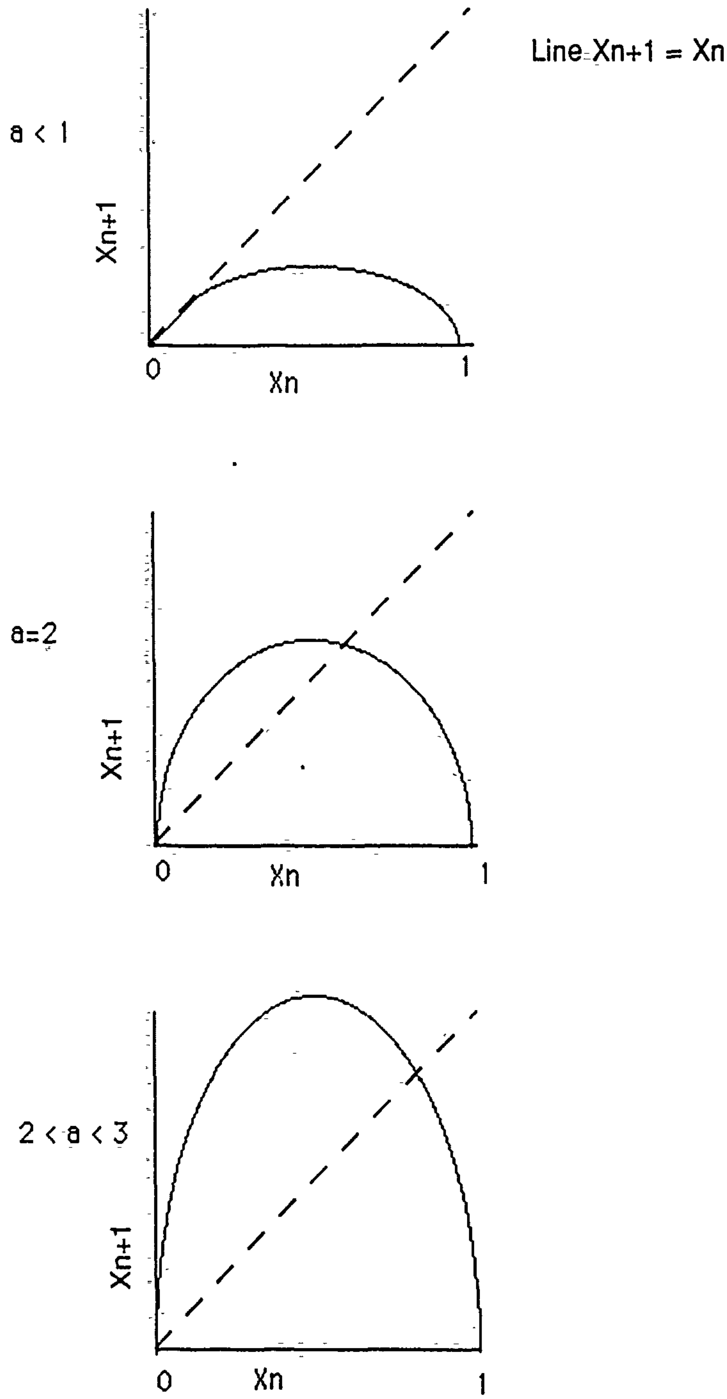


Figure 6: Typical Form of the Relationship between Xn+1 and Xn.

Figure 16.2 : Tech Drawings

Overview of Neural Networks

by

David Petrillo

Rome Air Development Center
Universal Energy Systems
Dr. Raymond A. Liuzzi
August 16, 1990

I would like to thank all the people at RADC for their assistance. A special thanks goes to Dr. Ray Liuzzi for his guidance and help. I would not have gotten far without him.

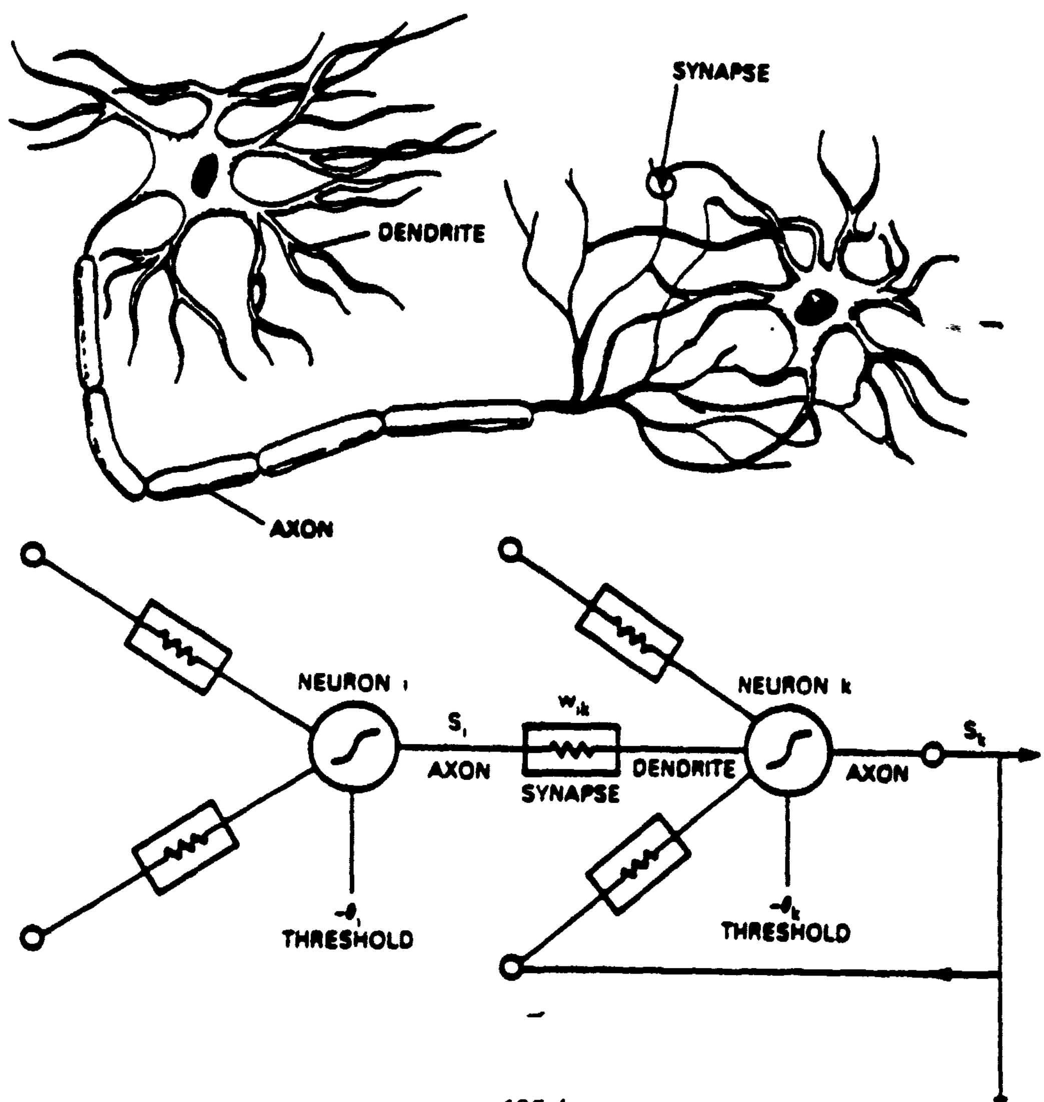
I. Introduction

The study of neural computing has been around for about fifty years but most of the progress has been made in the past twenty years. It is a system that imitates the way biological neurons are thought to operate. It offers advantages over conventional computing in several areas. It can arrive at solutions to a problem much quicker because it works in parallel. It can classify data into categories even if the data is incomplete or jumbled. Neural networks are best suited for finding relevant information from confusing input. This is very useful for radar systems and laser imaging where it can determine information about an object from the signal received.

II. Biologic and artificial neural systems

The human brain is estimated to have over ten billion neurons that combine in over 10^{15} interconnections in the body [1]. A single neuron is composed of the cell body and several dendrites that connect to other neurons through synapses. The cells send impulses down the dendrites and across the synapses. The next cell adds up all the impulses that come into it and if it passes a certain threshold it will fire an impulse to other cells.

Artificial neurons operate about the same way except that the dendrites become wires and the synapses become variable resistors. Artificial neurons can be programmed with different activation functions. Figure one is a diagram of biological neurons and artificial ones.



III. Neural networks

One of the most interesting aspects of neural networks is their ability to learn. They do this by adapting the weights between the cells until the input produces the desired output.

There are two basic methods by which neural nets can learn. They are called learning with a teacher and learning without a teacher [14]. Learning with a teacher requires that an external teacher monitor the results of the net and notify it whether it is right or wrong. This teacher can either be a human or a different computer or another part of the same computer. In learning without a teacher the network classifies the data into clusters based on their similarities.

IV. Types of networks

There are five major classes of neural nets. They are called hopfield, hamming, ART, perceptron, and kohonen [14]. They are classified based on the type of input and the method of learning. The first three networks can only receive binary input in which the individual bits are either on or off. The last two are capable of processing continuous values somewhere inbetween.

The hopfield net receives binary input and learns with a teacher. It is composed of an group of neuron usually arranged into a square. Each cell is connected to every other cell by small and random weights. The teacher applies a pattern to the cells and then the network learns. If two cells have the same value then the weight between them is increased. If they have different values then the weight is decreased. One drawback of this is that it has a limited number of patterns it can learn at the same time.

The hamming net has a layer of input cells and a layer of output cells. Each output cell is taught to recognize a certain input pattern. The net calculates the number of input cells that are different from the pattern learned by the output cells. the output cell that has the least amount of difference is selected as the winner.

The adaptive resonance theory was developed by Carpenter and Grossberg. It is similar to the hamming net except that it can learn without a teacher. It computes the difference between the input and each of the outputs. If the input is sufficiently close to one of the output it is placed in that class. If it is not close to any of them a new class is formed for it. This net can learn more patterns than the hamming net but has trouble with noisy inputs.

Perceptrons are simple nets that can easily separate their input into two separate classes. A single layer perceptron with two inputs separates them into two regions bounded by a hyperplane. The results of these are easily understood when plotted on a graph with the axes being the values of the input cells. The decision boundary is a straight line that divides the classes. Perceptrons with more than one layer can produce more complex boundaries than a straight line. The maximum number of layers required for any problem is three. Three layers can separate a region into arbitrarily complex areas. Perceptrons require that a teacher be present when learning. Figure two shows the boundary areas formed by different perceptrons.

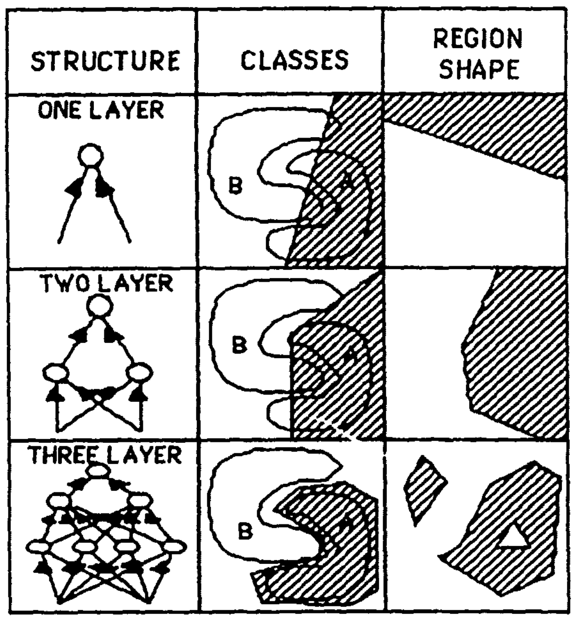


figure 2.

Kohonen feature nets can be trained without a teacher. While learning they distribute themselves evenly over a two dimensional plane which represents the inputs. The density of the cells in an area is determined by the frequency with which the inputs are activated. If the inputs in one area are active more often than the inputs in another then there will be more cells clustered around that area. This allows maximum sensitivity to the range of inputs being received.

V. Current status and applications of neural computing

Applications for neural nets are becoming more common. But there have been few systems marketed for general use. I will describe a few systems that have been developed. They include methods for analyzing and classifying input for computers. One of them can even operate a robot.

Machine vision has been attempted by many conventional computers but they usually deal with just one kind of input like boundary, motion, and shading. Usually they do not perform well outside of a laboratory. Neural networks can analyze several type of data. This allows them to overcome noise and other interference better. One such system is the Boundary Contour System (BCS) developed by Stephen Grossberg [5].

Sonar target identification is useful for locating undersea mines. It is often difficult for computers and even humans to distinguish between mines and clutter on the ocean floor. A neural network has been trained to identify cylinders or rocks from the sonar signal. After it was trained it could correctly identify the object 90% of the time. This is almost as good as humans or conventional computers. With improvements in neural technology it could get even better [5].

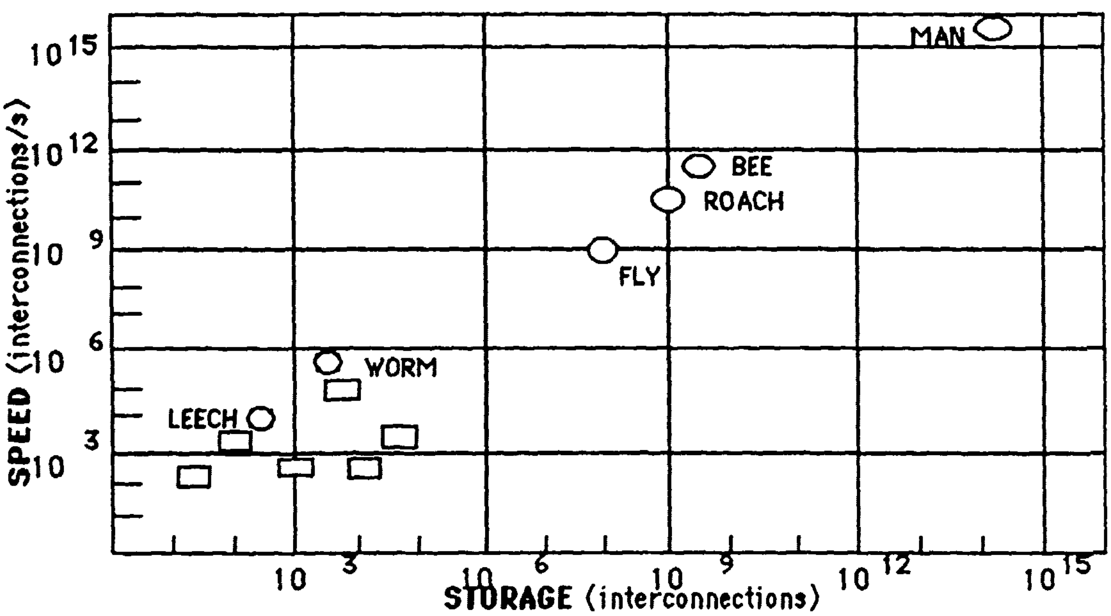
A multi-layer perceptron has been trained to recognize vowel patterns spoken by different people. This task has been difficult for computers because of the variability in the way people speak and the need for real time processing. The network receives input from the frequencies that makes up the sound. The error rate of the system was the same as a conventional computer [5].

The next network is a character recognizer developed by Kunihiko Fukushima called the neocognitron. The neocognitron consists of many layers with feed forward and feed back connections. It recognizes segments of patterns by learning and combines these features at higher levels. This system is capable of identifying any set of characters after learning them. It is not affected by deformations or changes in size or position of the character. Instead it work on similarity of shape. The feed back connections allow it to focus its

attention on a pattern so that it can identify multiple characters presented in the same input [7].

A forklift robot at Martin Marietta is controlled by a neural network. Its job is to insert the forklift into pallets placed irregularly on a moving conveyor belt. This is difficult for conventional computers because of the complex motions. They have to solve many equations to determine the correct movement. The neural network looks up the desired motion in a table that was formed during learning. This network learns very fast and is quite competent at its job [5].

Most of these networks are on about the same level as conventional computers. When more advanced hardware and software are developed they can be expected to surpass computers and maybe even humans. Figure three compares the capabilities of biological networks and current applications. The square boxes are the applications just explained. They are described in terms of interconnections and interconnections per second. While there has been much progress made, it is evident that we have a long way to go before we come close to a man or even a bee.



VI. MacBrain: a neural network simulator

While working at RADC I had access to a neural network simulator called MacBrain [4]. This program allows the user to design and test his own neural networks. It allows him to see the step by step operations of a neural net. It comes with several tutorials that help to introduce someone to neural nets. Each cell in the network has several variables that can be changed independently. A flowchart programming language is included that can automate net building or learning. The only drawback of this program is that it operates slowly and has a limited memory. This prevents the building of complex nets with many cells and connections.

I greatly enjoyed the opportunity to use this program. I built some small nets that could perform logic operations like AND, OR, etc. I also built a net that could take several input cells in a binary pattern and condense them into one cell. MacBrain is fun to use to create small nets like those but it lacks the memory and speed necessary to create anything that is useful.

VII. Future possibilities for neural networks

Figure four shows the requirements for current applications in black, the capabilities of simulators in gray, and the technological advances that will improve them. Gallium arsenide (GaAs) and charge coupled devices (CCD) will allow for an increase in the speed of simulators. Three dimensional chips and RAM technology will increase the number of interconnections possible. Multiprocessing and optical computers will expand the boundaries in both directions. Very large scale integration and very high speed integrated circuits can increase the speed but don't allow for many interconnections [5].

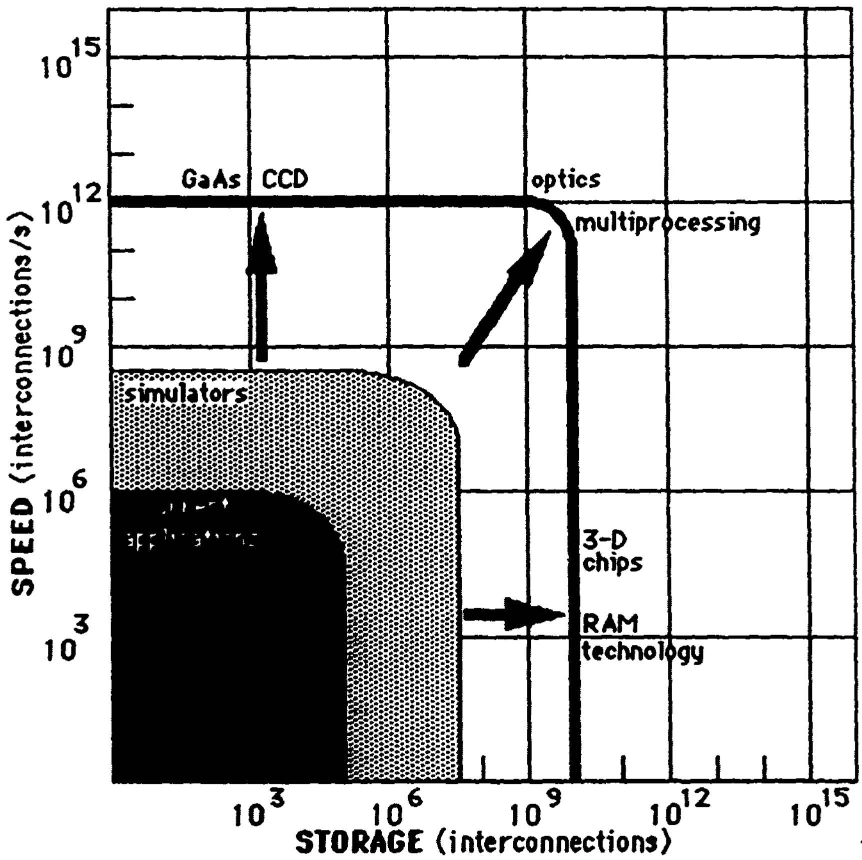


figure 4.

One important use for neural networks would be in applications related to national defense. Current surveillance techniques can't keep up with the flood of information coming from satellites and other sources. During a war it would become even more critical. Artificial intelligence programs take too long to develop and are not flexible enough. Neural networks have a great deal of promise in these areas.

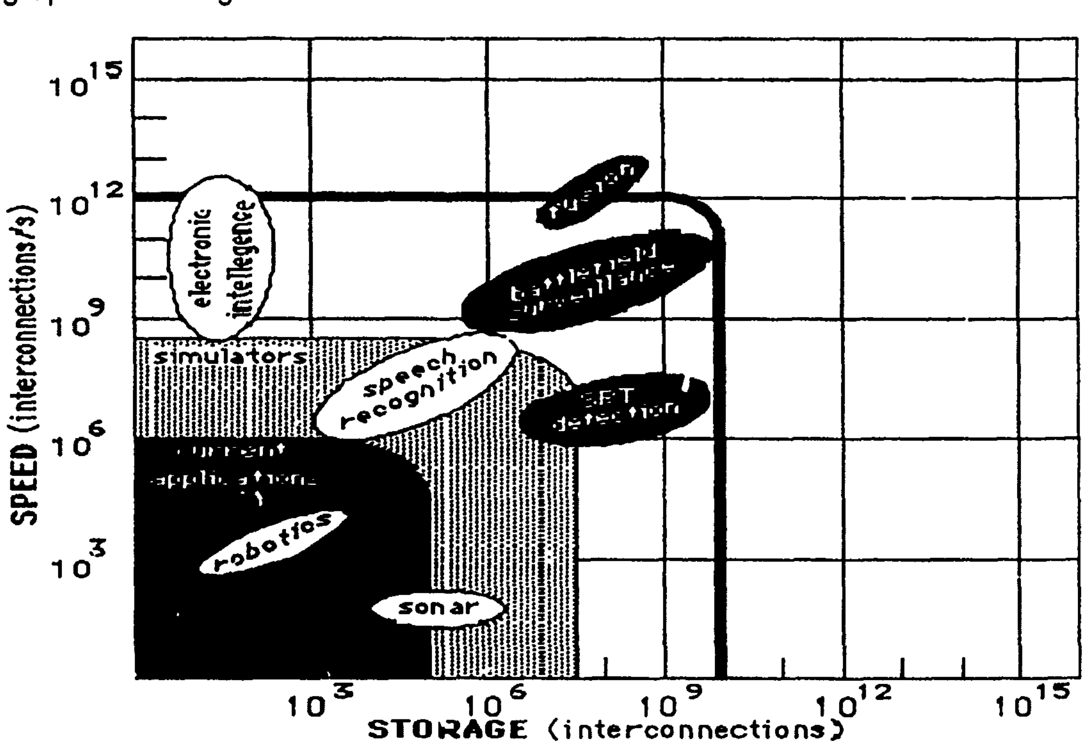
There are three categories of applications that neural nets could be used for. They can be used to detect stealth aircraft, quiet submarines, and mobile ground targets. They can be used to analyze data from satellites, and they can perform multi sensor fusion in battlefield conditions.

Satellite tracking of strategic relocatable targets could be accomplished with neural networks. This would just be feasible at the edge of today's simulators. One problem is the high rate and volume of the data which would be analyzed in real time.

Sonar array processors can be used to detect quiet submarines. This is similar to the problem of speech recognition because each sub has a distinct acoustic signature. This problem could be implemented with current technology. Detection of aircraft with radar is very similar to this.

Battlefield radar and infrared surveillance could detect well hidden equipment through all types of conditions. This system would have very high requirements because of the high resolution needed. It will be a while before technology advances to this level.

Figure five compares the requirements for these systems on the same graph used in figure four.



VIII. Conclusion

Neural networks are a unique and interesting way to approach some of the problems of conventional computers. Most of the advances in neural networks have occurred in the past ten years. During that time there was not a great deal of support from the government and industry. There was a great deal of progress made anyway. If researchers got additional support then I feel advances would come very quickly.

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SECTION I

ACKNOWLEDGEMENTS

I would first like to thank the people at Universal Energy Systems for giving me a chance to work again at Rome Air Development Center. Also I would like to thank UES for giving me a chance to work with a great mentor Dr. Lois Walsh. Next I would like to thank my mentor Dr. Lois Walsh for all the help and guidance she has given me this summer. Whenever I had a problem she would be there to help me no matter how busy she was. That is what I think I am most grateful of. Next I would like to thank Mark Esposito a summer engineering assistant form RPI for helping me with the problems I had with Lotus. I would also like to thank him for teaching me how to work on a vacuum system. Last I would like to thank everyone in RBRE for all the help they have given me. They have been a great group of people to work with.

SECTION II

INTRDUCTION

This summer I have been working with Dr. Lois Walsh at RADC/RBRE. I was given the project of running standards for the PHI 600 Scanning Auger Multiprobe. The PHI 600 Scanning Auger Multiprobe is used for detecting elements on surfaces. The Scanning Auger focuses high energy electrons through a series of electro-magnetic lenses to a fine beam onto the specimen. Auger electrons are emitted from the surface along with many other different types of radiation. Auger electrons are from the atoms inner shells. Detection of the Auger electrons will give a characteristic spectra for determination of which elements are in a sample.

To learn how to use the PHI 600 Scanning Auger Multiprobe I read the instruction manual and watch instructional video tapes on how to run the system. These video tapes were by Denny Paul an expert on the PHI 600 Scanning Auger Multiprobe. Also my mentor Dr. Lois Walsh helped me get familiai with the system so I would be able to run it by myself.

SECTION III

EXPERIMENTAL

This summer I have been working with the Perkin Elmer PHI 600 Scanning Auger Multiprobe running Standards for Auger Electron Spectroscopy. My mentor has had me do this so we can compare ours to similar standards. We can use our sensitivity factors to calculate atomic concentration of an element in a certain compound.

For every standard acquired I would look at it and determine if there was any surface contamination. If there was not any contamination then I would acquire the data as received. If there was contamination then I would sputter with Argon ions until the sample was clean. However if the sample did not remain clean then I would sputter while acquiring the data. Other times sputtering while acquiring data was necessary to alleviate charging problems. I would either have to sputter at X = .01 or X = .1 where X is equal to emission scale. Some standards were sputtered at X = .1 because sometimes sputtering at X = .01 would not get rid of the charging problems.

The standards I have looked at and completed are: Ag_2Te, B, Bi_2Te_3, C, Cr, InSb, InP, GaP, GaAs, Cu, FeS_2, CdS, Mg_2Sn, Ni, Pd, Pt, Si, Sb, PbTe, ZnS, and Ag. I also looked at some other standards but was unable to acquire them because sputtering at X = .01 and X = .1 did

not get rid of the charging. These standards are: Al2O3, BN, KBr, LiF, MgO, NaCl, SiO2, and four glass standards that were on the sample. The reason these standards charge is they are nonconductive. The surface of the sample accumulates electrons causing the Auger electrons to be shifted in energy.

Acquiring the data for these standards took me most of the summer. The first thing I had to do was make sure I was on the standard that I wanted to look at. After I was on the standard I had to move the beam voltage to 3kv. After I did that I had to maximize the beam current using the emission voltage but I had to make sure that the emission current did not go over 100 mA. When I was done maximizing the beam current I would set it back to 100 nA using the condenser lens. Next I would turn off the beam current monitor so I could look at the sample. I was able to look at samples because the Auger has a Scanning Electron Microscope. To look at the sample I had to turn up the high voltage. Once I got an image I would focus it this is done with the objective lens. After I focused the sample I would magnify it. This is so I could pick the best spot to look at and then focus it again.

Now I was ready to go to the computer. First would I do an EPA which stands for Elastic Peak Alignment. Next I would do a RAP which stands for Rapid Acquisition Parameter. What I had to do when I did a RAP was get the peak centered around 3000 ev and in the focal point of the Auger detector. I would do this by changing the Z-axis. After that I would a Survey then go into the editor to see if everything was set up right. Finally I acquired the data which would approximately five minutes. When the computer got done

acquiring I would save the raw data. After I looked at the spectra. To do this I had to differentiate, after that I smoothed the raw data. Once I got the spectra I would print. After I did that I would find the peak heights and label them on the print out. Now I have to do all of that for 5kv, 10kv, and 15kv. You can see that acquiring data for all kv's took quit a long time.

After I finished acquiring the data I had to find the best way to process it. I found Lotus to be the most effective way of processing the data. I feel this way because the computer will do all of the mathematical computations.

To calculate the sensitivities of the standards with respect to silver I would first calculate the intensity of the silver standard. To do this I used the equation:

$$I = P * SF / Y$$

The different standards can now be normalized to silver. For elements I used the equation:

$$S = P * SF / Y * I$$

For compounds I used the equation:

$S = P * SF / Y * I * N$ For each element in the compound

The abbreviations are:

I = Intensity of silver P = Peak to Peak height (mm)

SF = Scale Factor (cts/div) S = Sensitivity

N = Total number of elements in a compound / number of elements in part of compound

Y = mm / div

I put some standards into the computer and noticed that some of the sensitivities were off when compared to other calculated

values. So I started to investigate the problem. I found that I was trying to compare V/F graphs to Pulse-Count graphs, which are not compatible. Because of this I had to acquire compatible P-C and V/F spectras of Ag. After that I was able to put the rest of my standards into Lotus and compare like graphs. Then I was ready to start my sensitivity graphs. I decided to use a line graph but it did not look anything like the books. So I plotted the points on log paper which when compared to the book's graphs were similar but not exact.

Now that I had my graphs done it was time to sort all the data I had collected. I decided to put the data in a book so that when my mentor or someone else needed the data they could easily find the required spectras. I put Ag standards in the front. Next is a list of the standards with elements in order by atomic number and compounds in alphabetical order. Then comes the 3kv sensitivity graph and all the spectra behind that. The 5kv, 10kv, and 15kv are in the same order as the 3kv graphs are.

Now it was time to see how good the sensitivities I had acquired were. So my mentor had two samples of InP that she wanted to compare with my standards to see what the concentration of In to P was in both samples. She thought that they each should have a ratio of 1 to 1. Using my sensitivities for In and P to calculate atomic concentrations, I found both samples had a In to P ratio of approximately 1 to 1.

SECTION IV

SEMINARS

This summer I attended several seminars: 1) Reliability of Ohmic Contact given by Dr. Arjun Saxina from RPI. 2) NiB films given by Dr. Jim Spencer from Syracuse University. 3) Reliability of Polyimide Films given by Drs. S. U. Babu and Don Rasmussen from Clarkson. 4) National Nanofabrication Laboratory given by Dr. Craighead of Cornell University. 5) Dap Series given by CO a division here at RADC. 6) Laser Chemical Vapor Deposition a Route to Novel New Materials given by Dr. Joe Chaiken of Syracuse University.

These seminars dealt with some topics I did not understand but I think I learned a lot out from them. I learned about areas of studies that I did not know existed. I think the information I got from these seminars will helpful will be helpful. I feel this way because the seminars were on the cutting edge research. That is they were on research of high technical experimental equipment.

SECTION V

CONCLUSION

As a test of the calculated sensitivities I compared my InP standard to two samples of InP the results were consistent with known composition. This correlation gives me confidence that the data I collected is accurate. I hope that my mentor Dr. Lois Walsh and anyone else who plans to use the data that I gathered here finds that it is useful to them.

I would like to thank everyone again for giving me a chance to work in a lab with hands on experience. I have learned a lot this summer that I think will be useful in my future . Also I have had a lot of fun in the process. It has been a great summer job and I won't ever for get all the people that helped me especially my mentor Dr. Lois Walsh.

SECTION VI

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II. Overview

I used and updated a custom database application and also created a database application that will be used by the IRRA branch to track their activities. My work of updating the Software Inventory Control System Database helped to make current the inventory in the Software Inventory Control System and will give the system managers more accurate information regarding their systems. The database which I created, the Advanced Sensor Exploitation Efforts Database, will be used to keep track of the programs that have been completed and those that are being worked on in the IRRA branch. I also worked on miscellaneous projects, such as transferring scanned images among incompatible computers, setting up computers for usage in the office. I also drew viewgraphs for use in technical briefings, using sketches drawn by the person giving the briefing as a guide.

III. Updating the Software Inventory Control System Database

After working for Joe Antonik of RADC/IRRA at Griffiss Air Force Base in Rome, New York, I feel that I have gained a greater idea of the utility of databases in a scientific community. The first database that I worked on was the Intelligence Cartographic Facility/Software Inventory Control System (ICF/SICS). It was designed and implemented by a contractor to RADC/IRR. Its purpose is to store information about the computer systems in the Intelligence Cartographic Facility (ICF).

The ICF is a computer facility that is used by three of the divisions of RADC. The purpose of the ICF is to handle intelligence and reconnaissance information. Cartographic information derived from reconnaissance is used for battlefield intelligence and management. Several minicomputers and mainframes outfitted for advanced image processing and sensor exploitation are housed in the facility.

The Software Inventory Control System (SICS) is a database application created in 4th DIMENSION, a commercially available graphical, object-oriented database made by ACIUS, INC. The hardware platform for SICS is an Apple Macintosh IIcx with 8 megabytes of

main memory, an 80 megabyte hard disk drive, a large screen graphics monitor and an Apple LaserWriter II NT. The SICS was developed under contract F30602-87-D-0089 Task 15 by Synectics Corporation of Rome, New York.

The SICS contains data regarding the computer systems in the ICF. The information is stored in records in the database and linked to each of the other relevant records via a relation between files. Information stored in the database includes:

1. The system name
2. Each system's components (monitors, CPUs, printers, etc.)
3. Each component's serial number, part number, age, etc.
4. Each component's maintenance contract information

Information regarding the maps stored in the ICF are also included as a part of the database.

I was involved in two activities regarding SICS. Over the course of the summer, I:

1. Made corrections to the existing data in the system, and
2. Added a pictorial map of the location of each system in the ICF.

Entering corrections into the system required a list of all changes that were required. After the list was obtained from the system managers, I found the data that needed to be updated and changed it to make it accord with the new information. A report was generated showing all of the new information and was returned to the system managers for their use.

By adding to the database a picture showing the location of each system in the ICF, I hoped to help visitors and maintenance contractors find the system that they were trying to find.

I started the process by finding the layout (output page) where the picture could best be displayed. I then added a picture field to the structure of the database and changed the layout page so that the picture would be displayed. Using the Macintosh clipboard and scrapbook, I pasted drawings of the ICF with appropriate shading locating the systems into the database. The process was then complete.

IV. Creation of the Advanced Sensor Exploitation Efforts Database

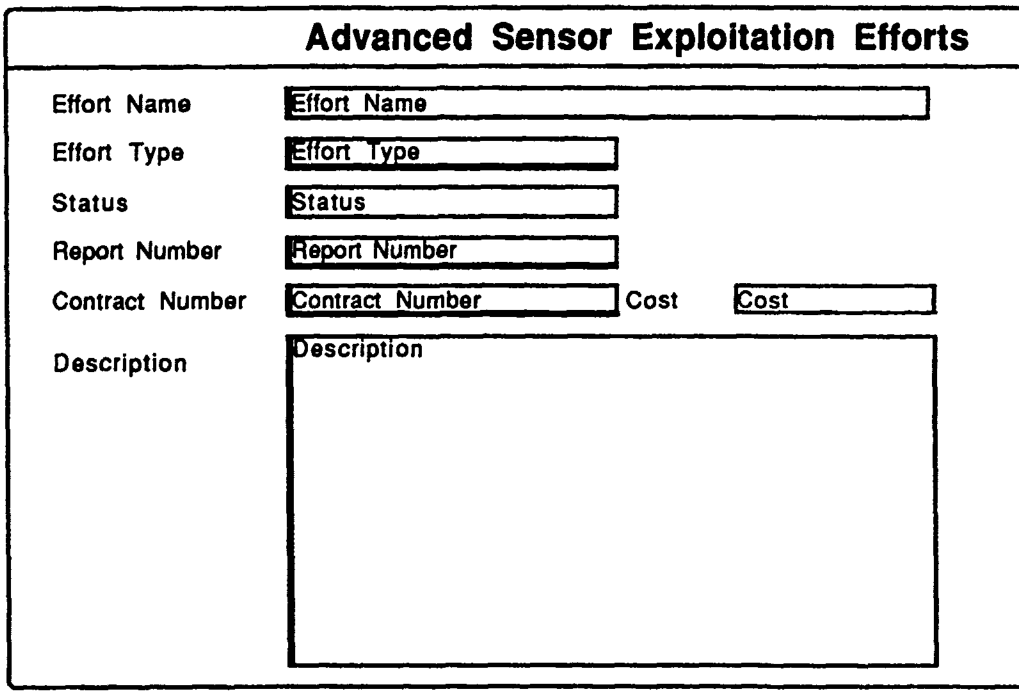
I was given an assignment to create a database that would be able to hold and display the various efforts that were in progress and had been completed by RADC/IRRA. The only design limitations were that the database must be able to run on an Apple Macintosh computer. The final database contains fields that contain, for each record:

1. the effort name
2. the effort's status (incomplete; date completed)
3. the effort's report number
4. the effort's type
5. the effort's contract number
6. the effort's cost
7. a brief description of the effort's purpose.

The IRRA branch of RADC specializes in exploiting the information concerning a battlefield that is obtained from various sources. The primary program within IRRA is the Advanced Sensor Exploitation (ASE) Program. The ASE program has the ability to correlate data from a Moving Target Indicator Sensor, Emitter Detector Sensors and an Imaging Source. The ASE system also has the ability

to continuously track high priority targets and identify critical targets, as well as being able to cue the sensors to observe specific areas or signals of interest. The ASE facility can also automatically issue alerts when friendly air force missions are potentially threatened by enemy Air Defense Units.

After the database structure had been designed, I designed the layouts that displayed the data. 4^{th} Dimension has two types of layouts: an input layout that is used when the user is entering data and an output layout that is used when the user is viewing many records. I originally created one input layout and one output layout. My mentor, Joe, suggested that it would be better to use one input layout and two output layouts, changing the output layouts with the type of data displayed. The output layouts display many records, one record per row and one field per column. If the database is currently displaying efforts of only one type, the database displays the effort name, report number and contract number. If the database is displaying records that have varying types, the effort name, status and type are displayed. If the user is manipulating only one record (data input or modification, or if a search limited the number of records to one), the record is displayed using the input layout. The input layout shows all of the fields, as follows:

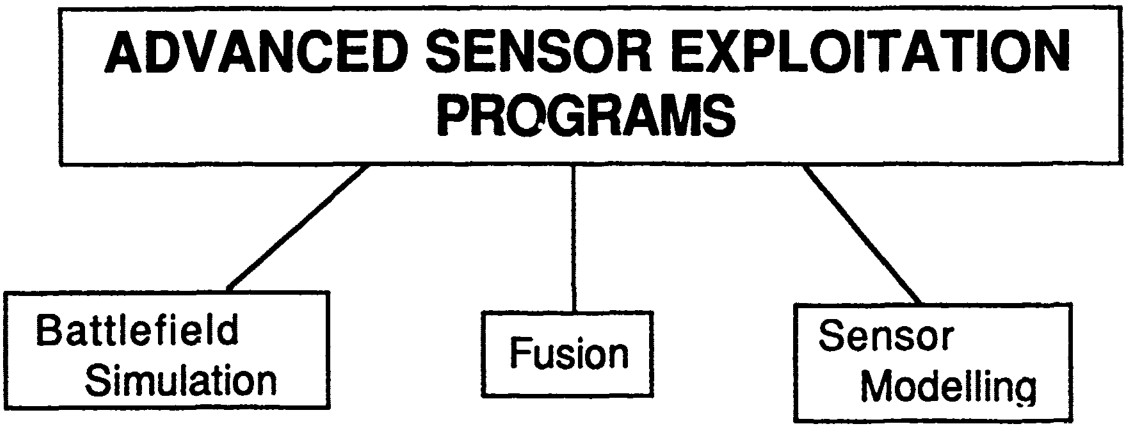


The text descriptions to the left of the boxes are labels; the text inside the boxes are references to fields. The names should be self-explanatory.

After the layouts were completed, I created some pull-down menus using the tools included in 4th Dimension. The menu items were then associated with 4th Dimension command scripts that performed the actions described in the menu items. For example, one menu is titled "**View**" and one of the items is "**All Efforts**" which, when selected, calls a script that displays all of the records in the database using the general output layout described above.

The final menu bar consisted of **File**, **Edit**, **View**, **Search**, **Sort**

and **Report** menus. The entire menu hierarchy is shown in Appendix A. Apart from the menu bar, Joe wanted a more conventional menu that would allow the user to click the mouse on a descriptive box and then see the data associated with that description. The resulting menu is shown below and duplicates the items in the **View** menu.



The large box at the top displays all of the records in the database. The three smaller boxes display only the records with the same type as that in the box. A behind-the-scenes view of this menu shows it to be an ordinary layout. The key is that it does not display any records or information from the records but is merely some text, graphics and buttons. The buttons were added in the 4th Dimension Layout Editor. They call the same scripts as the scripts called by the **View** menu choices with the same names.

The system can be used to generate reports of the data. The

Report menu allows the user to choose either of the two output layouts or the input layout to be used to guide the output data formatting. If the input layout is chosen, each record is printed using the input layout, each layout being put on a new page as necessary. The **Custom** item of the **Report** brings up the 4th Dimension Quick Report Generator which provides a clean "page" on which to place fields, lines and custom text, thus generating a report that is specifically tailored to each user's needs.

APPENDIX A

Menu hierarchy for Advanced Sensor Exploitation Efforts

Database

File
- Quit to User
- ----------------
- Quit to Desktop

Enter
- Enter records

View
- View All Efforts
- ----------------
- View Fusion
- View Battlefield
- View Sensor

Sort
- Sort by Name
- Sort by Report #
- Sort by Cost
- Sort by Effort type
- Sort by Status
- Sort Editor...

Search
- Search for Completed Efforts
- Search for Incomplete Efforts
- ----------------------------
- Search Current Selection...
- Search Entire File...

Report
- Names
- Contract Info
- All Info
- --------------
- Custom

APPENDIX B

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ARTIFICIAL NEURAL NETWORKS

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Introduction

This paper will provide an introduction of the basic principles and operating characteristics of Artificial Neural Networks, ANN. ANN which have been developed for classification, data association, pattern recognition, etc. will be described. Current research and development in the areas of hardware implementation, software simulation, and applications developed will also be described. Finally, several areas of potential research will be defined.

ANN are biologically inspired since they attempt to mimic the structure and functionality of biological neural network processing. The structure of an ANN consists of many simple processing elements, threshold devices, which are densely interconnected. The interconnects are weighted to inhibit or prohibit the processing element in achieving the specified threshold. The collective interaction of the simple processing elements "neurons" and their weighted interconnects provide for a high degree of computational functionality.

ANN have been proposed as an alternative means of computing since the 1940's, and have had limited success in specific application areas. ANN were first proposed for pattern classification. The simplest ANN, a single layer perceptron, can decide if an input belongs to one of two classes. In 1949, D. Hebb introduced a learning law which allowed an ANN to train or learn to recognize simple patterns.[3,9,11] The introduction of this learning law provided a means to adjust the weights of the ANN to achieve the desired output. Although the single layer perceptron could distinguish between two classes, it could only perform this function if the classes were linearly separable i.e., could be separated by a straight line. This limitation, the inability to perform the exclusive OR function, severly limited the capability of a single layer perceptron. The introduction of the multilayer perceptron has since eliminated this limitation however, only the recent introduction of learning laws for multilayer perceptrons has made it trainable.

ANN have also been proposed as an alternative to conventional Artificial Intelligence. The ability of an ANN to learn by example has produced ANN which can perform speech, vision, and pattern recognition. In contrast, conventional artificial intelligence requires the use of symbols and letters which are manipulated by rules to represent ideas or concepts.

Simple Node

The computing elements or nodes of a ANN are nonlinear, typically analog, and switch between states at slow speeds. A simple node sums N weighted inputs and passes the result through a nonlinearity. Thus a node can be described by the mathematical equation: X0*W0+X1*W1+...+Xn*Wn = Y = F(summation of Xi*Wi for i = 0 to n-1 - a nonlinearity) where X0-Xn represent the input, and W0-Wn represent the weights associated with each of the inputs. The values of the inputs to an ANN can be binary or continuous. Weights usually take on a continuous value between +1.0 and -1.0. Y is the output of the node and is usually equal to one if it is greater than the threshold value. The output of the node is zero otherwise. F acts as an activation function and is used to compress the range of Y such that Y can not exceed some predetermined lower limit regardless of the value of Y. Three common types of nonlinearities used in ANN are hard limiters, threshold logic elements, and sigmoidal nonlinearities. Nodes which incorporate temporal integration or other types of time dependencies have also been proposed.[3,5]

Simple Network

The single layer perceptron was the first and one of the simplest ANN proposed. Single layer ANN can perform simple pattern detection functions. The input layer distributes inputs but does not perform any computation thus, the input nodes are not considered to be neurons and do not constitute a layer. "A layer consists of a set of weights and the subsequent neurons that sum the signal they carry."[3] Each input element Xi is connected to each neuron through a separate weight Wi. Each neuron outputs a weighted sum of the inputs to the network.

The weights which are applied to the inputs are typically stored in a matrix. For example, for matrix W(m,n) where m equals the number of rows and n equals the number of columns then, W(3,2) equals the third input to the second neuron. Thus, the input vector is multiplied by the weight matrix. This is a common calculation in numerical analysis. Many ANN simulators use floating point co-processors to perform this computation.[14]

The adjustment of the weights provides training or learning for the ANN. Training is performed on a net so that the application of a set of inputs produces the desired outputs. Supervised and Unsupervised learning have been proposed as two ways of adjusting the weights. Algorithms have been developed for each of these methods.

Supervised training requires that each input vector is paired with a target representing the output. "An input vector is applied, the output of the network is calculated and compared to the corresponding target vector, and the difference (error) is feed back through the network and weights are changed according to an algorithm that tends to minimize the error."[3] The network is trained by cycling through the training pairs until a satisfactory level of performance is reached.

Unsupervised learning requires no target vectors for the output and no comparisons to predetermine ideal responses. Training contains only input vectors. The training algorithm modifies network weights to produce output vectors that are consistent. Training extracts the statistical properties of the training set and groups similar vectors into classes. Applying a vector from a given class to the input will produce a specific output vector. Output patterns can not be determined prior to training.

The training algorithms which have been proposed are mostly based on the concepts of Hebb. Hebb proposed a model for unsupervised learning in which the synaptic weights are increased if both the sending and receiving neurons are activated. Paths which are used most often are strengthened creating habit and learning through repetition. The Hebbian learning rule can be described by the following mathematical equation: W(i,j)*(n+1) = W(i,j)*n + a learning coefficient*Out(i)*Out(j).[3] W(i,j)*(n+1) represents the value of the

weight from neuron i to j prior to adjustment. W(i,j)*n is the value of the weight after adjustment. Out(i) is the output of neuron i and the input to neuron j. Out(j) is the output of neuron j. The learning coefficient determines the learning rate by controlling the average size of weight changes.

Rosenblatt, Widrow, and Hoff developed training algorithms for supervised learning.[3,5,9] The training method for supervised learning can be summarized as follows: (1) apply an input pattern and calculate the output Y. (2a) if the output is correct, go to step 1, (2b) if the output is incorrect, and is zero, add each input to its corresponding weight, or (2c) if the output is incorrect and is one, subtract each input from its corresponding weight. (3) go to step 1. This method has been used to train perceptrons since they are not self organizing and require supervised learning.

The Delta Rule is a further generalization of the perceptron training algorithm which allows for continuous versus binary inputs and outputs.[3,7] The delta rule can be described by the following mathematical equation: S = (T-A). S represents the difference between the desired or target output T and the actual output A.

The single layer network (perceptron) provides a useful and informative introduction to ANN. However, Minsky showed that the single layer perceptron could not perform a simple exclusive-or function.[2] Thus single layer perceptrons can not classify inputs which are not linearly separable. "Linear separability limits single layer perceptrons to classification problems in which the set of points (corresponding to input values) can be separated geometrically."[3] This means that two inputs can be separated by a straight line, three inputs by a plane, and four or more inputs can be separated by a hyperplane or n-dimensional space. This limitation was overcome by the introduction of additional layers.

Multilayer Networks

The introduction of multilayer network provides for more complex ANN with greater functional capability. Multilayer networks overcome many of the limitations of single layer networks. Decision regions can

be formed for the exclusive-or problem using multilayer perceptrons.

Multilayer networks (perceptrons) are feed-forward nets with one or more layers of nodes between the input and output layer of nodes.[5] The additional layers contain "hidden nodes". Multilayer nets are formed by cascading single layers. The use of a nonlinear activation function is required between layers to make a multilayer network have more computational power than a single layer. The output layer is calculated by multiplying the input vector by the first weight matrix and then by the second weight matrix if there is no nonlinear activation function.

Multilayer networks provided a solution to the computational limitations single layer networks however, the lack of adequate training algorithms had prevented multilayer ANN from achieving their full potential. The Delta Rule which was used to train the single layer perceptron can not be used to train multilayer networks because it is unable to determine the connection weights of hidden layers. An algorithm used to train multilayer networks was introduced by Werbos as early as 1974 however, it wasn't until 1986 that Rumelhart, Hinton, and Williams described the backpropagation algorithm.

The introduction of the backpropagation has played a major role in the resurgence of interest in ANN in the 1980's. Backpropagation allows assignment of the Delta Rule to neurons in the hidden layer which can not receive direct feedback from training patterns in the outside world. Backpropagation provides a more general means of calculating the weights and is described by the following mathematical equation: S(p,j) = (T(p,j)-O(p,j))f'(j)(net(p,j)).[7] This equation is similar to the Delta Rule except for the addition of f'(j)(net(p,j)) which is a derivative of a "squashing function". The squashing function is a special type of threshold function that is differentiable and nondecreasing. It operates on the sum of the inputs to a unit (neuron) in order to determine the unit's output. In a linear system without the squash function, the output of a unit is equal to its input.

The Delta Rule, S=(T-A), for a neuron in a hidden layer can be computed usi the following mathematical equation: S(p,j) = f'(j)(net(p,j))*Summation(k)*S(p,k)*W(k,j).[7] This equation represents a recursive definition in which the neurons delta, S, is determined by

the derivation of its squashing function multiplied by the weighted sum of the deltas to which the neuron sends its output. S(p,k), a given delta term in the summation, is weighted by the strength of the connection from neuron j in the hidden layer to neuron k which is the source of the delta.

The computation of deltas for the internal neurons is performed by propagating back through the system errors that are based on observed differences between the values of the output nodes and a training pattern. "The deltas are first computed for the output units, and these are then propagated backward to all units pointing to the output units in the layer below. These units in turn, propagate their received deltas backward to units that point to them, and so on, until the input level is reached."[7] Deltas change the weights of a network much like the Delta Rule using a gradient descent heuristic.

The use of multilayer networks and backpropagation provides ANN with the ability to induce input/output mappings of arbitrary complexity. This added functional capability allows ANN a capability to represent useful abstractions of the outside world. Hidden units often reduce the number of connections required to represent a mapping.

Application of Artificial Neural Nets

This section provides an introduction to several ANN models which are used to implement specific applications. Where it is possible, comparison is made between using an ANN versus using conventional computing techniques to implement the application. The three major application areas which have been impacted by ANN are pattern recognition, data analysis, and control systems.

Several ANN have been developed which can be used for extracting features of patterns, classification, and association. These nets represent highly parallel building blocks, i.e., these nets can receive input in parallel, and can be used to form multilayer multifunctional networks. The single layer net can implement algorithms required by Gaussian maximum-likelihood classifiers and for optimum minimum-error classifiers for binary patterns corrupted by noise. Most traditional classifiers, such as the Gaussian classifiers are trained with

supervision using labeled training data. Nets trained without supervision, such as Kohonen's feature map forming nets, are used as vector quantizers or to form clusters. More sophisticated ANN, such as the three layered feed-forward net, a multilayer perceptron, can generate the decision regions required by any classification algorithm. In some cases, a net implements a classical algorithm exactly.

Classifiers are used to determine which of M classes is most representative of an unknown static input pattern containing N input elements.[5] Traditional classifiers use two stages. The first stage computes matching scores for each class, and the second stage selects the class with the maximum score. Inputs to the first stage are symbols representing values of N input elements. An algorithm computes how closely the input matches the exemplar pattern for each class. Exemplar patterns are patterns which are most representative of each class.

Probabilistic models are used to model the generation of input patterns for exemplars and the matching score represents the likelihood or probability that the input pattern was generated from each M possible exemplars. Strong assumptions are made concerning underlying distribution of input elements. Parameters of distribution can then be estimated using a training data. Multivariant Gaussian distributions are often used.

An adaptive ANN classifier can be used to perform three different computational tasks. It can be used to identify which class best represents an input pattern even if the inputs have been corrupted by noise. It can be used as a content addressable or associative memory. This classifier produces a class exemplar based on the input pattern used. The complete pattern can be produced even if only a portion of the input pattern is made available to the net. The adaptive ANN classifier can also be used to vector quantize or cluster N inputs into M clusters. Vector quantizers can be used to reduced the number of bits necessary to transmit analog data in image and speech transmission systems. This is also known as data compression.

The Adaptive ANN classifier inputs N values in parallel to the first stage via N input connectors. Each connection has an analog value which can be binary (2 levels) or vary over a large range for continuous

valued inputs. The first stage computes matching scores and outputs the scores in parallel to the next stage over M analog output lines. The maximum of these values is then selected and enhanced. The second stage has one output for each M class. The output of the most likely class will be high (stronger), other outputs will be low.

Adaptive ANN classifiers which are more sophisticated can be developed by using more stages and incorporating other modalities or temporal dependencies. The ANN classifier output can also be sent back to the first stage of the classifier to adjust the weights using a learning algorithm.

The Hopfield Net is a classifier which was proposed by John Hopfield.[5] Hopfield proved that his net converges when the weights are symmetrical (T(i,j)=T(j,i)). Convergence occurs when the output of the net reaches a constant/usable state. The net can be used as an associative memory or to solve optimization problems. The Hopfield net is limited in the number of patterns it can store. If too many patterns are stored, the net may converge to a spurious pattern different from all exemplar patterns. The Hopfield net is also limited in that an exemplar pattern may be unstable if it shares many bits in common with another exemplar pattern.

The Traveling Salesman Problem is a classical optimization problem which has been implemented using a Hopfield net. The Traveling Salesman Problem requires finding the optimum or shortest possible route for a salesman to visit n cities and return to the starting point. This problem is known as an NP complete (nondeterministic polynomial) problem which has no known solution except to try all possibilities. Researchers have applied heuristic methods to find acceptable/optimal solutions to this problem.

Conventional computers have been used to solve this problem by measuring each route one by one and comparing them to find the optimal solution. Hopfield and his associates at Bell Labs implemented the Traveling Salesman Problem on an ANN and found that the ANN was one thousand times faster than a conventional computer. The answer provided by the ANN was optimal fifty percent of the time, and was one of the two best ninety percent of the time. The use of an ANN provides a tradeoff

of speed versus the exact solution provided by a conventional computer.

David Johnson at ATT Bell Laboratories later compared the results obtained by the Hopfield net with a heuristic algorithm developed by Lin and Kernighan.[4] Johnson found that the Lin and Kernighan algorithm calculated the traveling salesman problem for up to fifty thousand cities and achieved the optimal solution ninety eight percent of the time. He also found that the Hopfield network only calculated results for thirty cities and only achieved the optimal solution eighty two percent of the time. The results of Johnsons' findings seriously questions the applicability of the Hopfield net for solving the traveling salesman or any large optimization problem.

The Hamming net, proposed by John Moody, is another example of an optimum error classifier.[4,5] This net is used to calculate the Hamming distance used by associative memories. Simple associative memories store M binary vectors of length N. "Given a binary input vector of length N, the function of the associative memory is to produce as its output the stored memory vector with the smallest distance to the input u." The Hamming distance is the number of bits in the input u which do not match the vector stored in memory.

The Hamming net is composed of two subnets. The lower subnet calculates N minus the Hamming distance to vectors stored in memory, and the upper subnet selects the node with the maximum output.

The associative memory function has been used to decode a binary error-correcting code used on a noisy channel. This function has also been used to encode the output of an information source to compress the data that is to be transmitted over a communication channel.

The Carpenter/Grossberg Classifier is an ANN which has been proposed for Adaptive Resonance Theory, ART.[4,5] ART networks and algorithms provide ANN with the ability to learn new patterns while preventing the modification of patterns which have been learned previously. Previous ANN proved to be unstable, would not converge, if new training vectors were introduced. Carpenter and Grossberg provided examples of such unstable networks in 1986.

This ART network can form clusters and is trained without supervision. The net implements a clustering algorithm which is similar to a sequential leader clustering algorithm. The first input is used to form the first cluster exemplar. The second input is then compared to the first cluster exemplar. The second input is then clustered with the first cluster exemplar if it is less than a specified threshold otherwise, a new cluster exemplar is created. This process is repeated for all inputs. The number of clusters created depends upon the threshold and the distance metric used to compare inputs to cluster exemplars.

NETtalk, developed by Sejnowski and Rosenberg, is a three layer network used to synthesize speech from text.[4,8,11] Classical text to speech synthesizers use two stages. The first stage translates text into a representation for sounds, and the second stage uses the representation to control a device that can generate sounds. NETtalk also uses two stages the first of which is performed using an ANN.

NETtalk was trained using the backpropagation algorithm. The training set consisted of one thousand words which were presented to the network thirty thousand times. The network was able to produce the correct translation of text ninety eight percent of the time using this approach. "The rules aren't put there", says Sejnowski, "they emerge". [8] NETtalk was trained within a couple of months.

In contrast, DECtalk, a commercial product developed by Digital Equipment Corporation is a system which uses conventional computer programming to perform the first stage to synthesize speech from text. This approach requires that the conventional computer programmer write a series of rules and exceptions to perform the task. Most conventional speaking systems which have been developed also use a pronouncing dictionary containing ten thousand words and then switches to rules if the word is not in the dictionary. The first stage of DECtalk required three years of development.

In addition to the previously described applications, ANN have also been used for data analysis ANN have been implemented for data analysis applications which use time series forecasting to predict trends in prices, performance of loans and insurance, and airline reservation

patterns.[14] For example, the Airline Marketing Tactician has been developed and tested by Belau Heuristics Inc., as an airline seat capacity management system. Nestor Inc., is currently field testing an ANN application which produces risk assessment on mortgage insurance applications. This ANN has been trained to do predictive modeling using the experience of the company's underwriters.

Artificial Neural Network Hardware Implementations

This section provides a review of ANN circuits which have been implemented in hardware. The maturity of hardware has also played a major role in the resurgence of ANN during the 1980's. The introduction of massively parallel machines, such as the Connection Machine, now provides researchers with a computer architecture with many simple processing elements which are densely interconnected. The availability of cheap computing power provided by VLSI has also allowed researchers to implement ANN circuits. ANN circuits can be built using operational amplifiers as neurons, and wires, resistors, and capacitors for synaptic connections.[9] The parallel interconnection capabilities of optics have also been exploited.

A simple ANN circuit can be implemented as a flip-flop with two stable states.[9] Flip-flops can be built from a pair of saturable amplifiers. Amplifiers mutually inhibit each other; a high output by either one will drive down the input of the other thus creating stable states.

A flip-flop trajectory, the path taken to a stable state, is associated with a mathematical quantity called the computational energy E. E is characterized by a mathematical formula describing the amplifiers and the strength of the interconnections. E can be plotted as a continuous surface containing two valleys near the voltage configurations (+1, -1) and (-1, +1), representing the two stable states. This surface can be altered by changing the input external sources of current or by changing strengths of connections. One flip-flop can represent two states and provide two solutions. N flip-flops can be be used to represent n states, and provide n solutions.

Simplified biological neural networks and ANN share a common mathematical formulation as a dynamical system. The dynamical system is a system of several interacting parts whose state evolves continuously with time. Dynamical systems evolve depending on the form of the interactions. The behavior of ANN circuits also depends on the details of their interactions.

The Collective Decision Circuit, CDC, is an example of an electronic ANN circuit which was developed by David Tank and John Hopfield.[9] Computation of a CDC, a dynamical system, begins at an initial state, moves through a series of changes to arrive at a state representing the answer using a "configuration space". In a digital computer configuration space . defined by a set of voltages for its devices. Input data and a program provide initial values for voltages. Values change as computation proceeds and finally reaches a final configuration. Collective decision circuits do not compute instructions step-by-step, and do not advance and then restore the computation path at discrete intervals. The CDC channels in one continuous process.

The computational energy of a CDC can be seen as a landscape of hills and valleys. The circuit computes by following a path that decreases the computational energy until the path reaches the bottom of a valley. CDC circuits might prove to be effective for solving problems involving global interaction between different parts of a problem. CDC might also be good for certain optimization problems.

The Silicon Retina, developed by Carver Mead & Associates, is another example of ANN circuitry.[17] The system performs the same visual processing functions of the human retina, and is an analog emulation of the human nervous system. The silicon retina consists of 3-by-4 inch boards of analog circuitry connected to a camera lens. The main chip is an array of photo sensors that emulate the photo receptors of the human eye. External objects passed across the lens are processed by an analog array processor. The image is then displayed on a video monitor.

An animal vision function is "accomplished by photo receptors which compute the average of local light intensity and then comparing this value to the value of the incoming light intensity from the external

source."[17] The optical nerve receives the differential of these values and identifies the external object. The silicon retina array processing chip performs a similar function.

The silicon retina represents a "gain control mechanism". Edge enhancement is used to separate the edges of the object from uniform background lighting. Although analog processing can achieve one hundred thousand times the efficiency of digital computing, present day transistors lack uniformity and create inconsistency. The human brain also contends with an inconsistency created by the nervous system but adapts by performing an averaging on the values of incoming signals. Such adaptation would be difficult to achieve in silicon.

Optical devices have also been proposed and implemented as ANN circuitry.[18] Optical processing elements can communicate through beams of light in free space. This allows processing elements to be interconnected without the use of wires which create communication bottlenecks in VLSI chips. Free space optical interconnection also provides for interconnection topologies which are not confined to the planar configurations required by silicon.

Holograms can be used to establish arbitrary optical interconnection paths between processing elements. Holographic images projected onto a photorefractive crystal are recorded in terms of the spatially varying refractive index. When the crystal is exposed to light, electric charges are generated in it that redistribute themselves according to the pattern of the illuminations intensity. Image information can be retrieved by illuminating the crystal with a light beam. Associative memory has been demonstrated using holograms.

Software and Simulation

The "system software" used by ANN, when discussed within the context of conventional computing, can most closely be associated with the learning algorithms previously discussed. These learning algorithms provide the control to an ANN. They describe how the weights are to be adjusted. The "application software" used by ANN, when discussed within the context of conventional computing, can most closely be associated with the inputs that are provided to the network, and the

outputs that the user wants to see. This training set does not provide any rules for how the computation is to accomplished. Thus, the learning algorithms must determine how the computation is accomplished.

Software simulation of the several ANN models discussed earlier, in conjunction with the floating point processing accelerator boards discussed earlier, is a major commercial thrust which offers tools for developing ANN applications for end users. ANN are usually represented as a dynamical system and are modeled as a set of coupled differential equations. Most of the ANN simulation programs are of the differential equation type.

ANN and Artificial Intelligence

ANN and AI have similar roots in that both are trying to achieve a level of intelligence.[4] The two disciplines were intertwined but differed in the late 1950's. ANN researchers concentrated on how the brain does things, while the AI researchers concentrated on what the brain did irrespective of how it was accomplished by the brain.

AI relies on the basic principle that thinking involves the manipulation of symbols. Letters or numbers can be used as symbols to represent specific ideas or concepts. These symbols can then be applied to a set of operations. For example, f=m*a or a=f/m. However, this approach has not provided AI with an effective way to perform speech and vision computation.

ANN offer a different type of AI; instead of relying on rules, AN learn by example. ANN can generalize from previous examples, even if noise or distortion has been introduced. ANN can also modify behavior in response to new and changing inputs and abstract from the essence of a set of inputs.

An Expert System, which is an implementation of AI, uses rules such as IF/THEN to represent knowledge.[7] ANN knowledge is represented in the neurons connections and weights. Expert Systems are driven by symbols generated by rule firing. ANN operate at a subsymbolic level since only numerically valued activation passes between neurons. Each neuron can be considered as a classifier or feature detector.

Input primitives such as sex, age, and height are examples of features. For each ANN there is a corresponding input unit for each feature with a firing rate which is dependent upon the extent to which the feature is detected in the outside world. The input units are connected to the classifier units. The classifier units threshold function can act as a boolean and or an inclusive-or. ANN represent continuous gradations based on the intensity of the input features. Rule based Expert System can not achieve continuous gradations.

Future Research

This section will discuss several ongoing and future research areas for ANN. Research in ANN, which was dormant in the late 1960's and early 1970's, has expanded dramatically in the 1980's with the introduction of learning algorithms for multilayer networks. In addition, the availability of cheap and more powerful hardware has provided parallel processing architectures for conventional computing and ANN systems. The ANN commercial industry, currently a ten to twenty million dollar business, is expected to grow to hundreds of millions within the next few years.[14] This expansion will provide additional funding for research.

ANN technology provides the potential to build systems which can mimic the behavior of an expert. Current Expert Systems require enormous amounts of resource and effort to construct rules which must be extracted from a domain expert. The rules must then be entered into the system and checked for potential inconsistency and incompatibility. Expert Systems are also brittle in that they can not abstract or make associations from fuzzy, noisy, distorted data.

ANN provide the potential to build Expert Systems without implementing rules. ANN are trained based on the inputs provided. However, much research has to be done to determine what the training set should be, or even if there is a proper training set. Maybe an ANN Expert System will continually learn in which case, it will probably adopt the principles of Adaptive Resonance Theory. If training the network becomes a continual process in which human intervention is required, the training time and effort could rival the time and effort

required by conventional AI approaches.

The ability of ANN to make abstractions and associations from fuzzy, noisy, and distorted data is inherent to ANN computation, but can these operating characteristics be applied to systems? What is the limit at which a ANN system abstraction will be acceptable for real world applications. This is also an open issue which will require more research.

ANN provide the potential for implementing large associative memories with fast access. ANN have been demonstrated for associative memory used for data encoding and decoding in communication theory. However, research on the use of ANN for large associative memory applications has not yet been addressed. John Moody has stated that "the long term applications of associative memories, as pure memories, have yet to be defined in any detail".[17] Associative memories are however, relevant to the problem of searching large data bases and to searching large sets of rules in AI expert systems. Access time is a major problem for large data/knowledge base systems.

Content addressable/ associative memories have been proposed for managing the index to very large data bases.[13] Associative memories search a memory based on the content of information, data, to be accessed. Conventional computers store information by assigning addresses which identify physical locations where the data is stored such as a sector or track on a disk. Indexing and search schemes which have been developed to minimize access time include: hashing, B-trees, inverted lists, pointer systems, etc. These indexing and search structures are usually implemented using associative memory. Electronic and optical schemes have been developed.

Associative memory implemented using ANN could also be used to process indexing and search mechanisms for large data/knowledge bases. However, the information would not reside in memory locations, it would reside within local minima, an entity, of a network. Thus, indexing schemes such as hashing, B-trees, and inverted lists could not be used. Local minima could be formed where several attributes/features combine to form an entity. For example, an employee data base might contain several features such as name, age, sex, and address. All names might

be strongly connected to form an entity called names. This entity, in turn, would be stored as a local minima in a network.

Information could be accessed by providing the network with one or several attributes, input data, to the network. The number of input and output nodes required is equal to the number of elements in each of the attributes combined.[2] The network would cycle for several iterations until it reached a steady state. Thus if a user input the name of a person, the ANN would output the person's name, age, sex, and address. If the user input an M for sex, the network would output the names of all the males. The ability of an ANN to accept one or more attributes and converge to a steady state provides for graceful de adation of the knowledge that can be derived from the output of the net. If the user inputs an age, say thirty, the network would provide little information about people in the database who were age thirty. However if the user input age thirty and sex male, the network could output the names and addresses of all the men in the database who were thirty.

The convergence of a ANN to a steady state is another area which is open to future research. ANN can converge to a local minima required to implement associative memory, they can also converge to a global minima required by a continuous mapping function. ANN which are required to converge to a global minima can become trapped in a local minima and vice-versa. The time it takes for an ANN to converge and the fact that an ANN may never converge for certain applications are also at issue.

The Hecht-Nielson Neuro Computer Corp. advanced the work of Kolmogorov to prove that a three-layer network will always converge to a global minima for any continuous mapping function. [10] However, new learning laws are still required for other types of mapping functions which need to converge to global and/or local minima. Learning laws which guarantee convergence also need to be developed.

Finally, there is the issue as to where ANN can solve NP complete, nondeterministic polynomial, problems more effectively then conventional heuristic methods. Scheduling tasks, such as the Traveling Salesman Problem discussed earlier, are NP complete problems. If a problem is NP complete then it is unlikely that a polynomial-time algorithm exists which can always find an optimal solution. The number of steps in any

solution to an NP complete problem is non-polynomial (i.e., exponential), dependent upon the size of the problem.[4]

Heuristics is a method which applies rules of thumb, insight, intuition, etc. to random problems which do not have an algorithmic approach. Random problems are problems which lack concise and complete definition. Random problems have high entropy. Entropy can be described as the amount of disorder or the amount of information needed to define the problem. For example, the Traveling Salesman Problem requires information about the distances from each city to every other city. Information Theory has also been applied to these types of problems.[18,19]

ANN implementations of NP-complete problems will require the development of new/refined learning laws to perform the optimization function. The number of input nodes of an ANN will be dependent on the size of the problem. A Traveling Salesman Problem with fifty thousand cities will require an ANN with fifty thousand input nodes.

Conclusion

This paper has attempted to review the many disciplines of ANN. Recent developments in mathematical theory have provided multilayer networks with algorithms for learning. The ability to train multilayer ANN makes new application development possible. The availability of cheap and powerful hardware make ANN circuitry possible. ANN circuitry inspires the development of new microelectronic chip and computer design.. ANN have achieved commercial application.

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LOCAL AREA NETWORKS

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SECTION I

INTRODUCTION

1. SCOPE

This report is a basic discussion of computer networks and basic knowledge associated with local area networks. Among those things discussed will be a short history of computer networking, a discussion of transmission media, and an evaluation of the basic types of local area network topologies with the advantages and disadvantages of each. The information within this report is basic and introductory, very little prerequisite knowledge is required.

2. PURPOSE

The purpose of this report is to gain a rudimentary knowledge in the basic tenets of computer networking. It is meant to provide understanding of the simple concepts of the fast-evolving world of networks.

3. BACKGROUND

As the logical progression and completion of a project begun with the mapping and diagramming of the computer networks in the C^2TL, this report is a compilation of information found in the sources mentioned in the bibliography.

SECTION II

LOCAL AREA NETWORKS

1. DEFINITION

Before we define "local area network" we must define "network" in general. An "electrical network is a structure composed of a finite number of interconnected elements with a set of ports or accessible terminal pairs at which voltages and currents may be measured and the transfer of electromagnetic energy into or out of the structure can be made."[1]

A local area network is distinguishable from other networks "by the area it serves, the speed at which information can be transmitted, the ease at which new devices can be added, and the simplicity of the basic transmission medium itself."[2]

2. HISTORY

The origins of local area networks seem to lay in research and university environments where fast, inexpensive transmission was needed between a number of workstations and/or data collecting stations. Local area networks form part of the continuing evolution of data transmission networks in general, and packet-switching technologies in particular.

Since the practicality of packet switching techniques has been realized, great importance has been placed on them in research systems, such as DARPA in the USA and at the National Physical Laboratory in the UK. Many national telecommunications authorities now have public networks that use packet-switching techniques.

One of the first networks to be developed and implemented using the techniques now associated with local area networks began as a very wide area network in which the cost and difficulty of providing normal cable links was exorbitantly high. The system was the ALOHA network in Hawaii which was set up to provide cheap and easy access for a large number of terminal users to central computing facilities. The feature of the ALOHA network was its usage of broadcast radio channel by all the users[3]. The terminal users must contend with each other for use of the radio channel if they wish to transmit data. Reception of data was universal; everybody had access to broadcast data.

In the original ALOHA system, packets of data were broadcast by the users and received by the central computer installation which is able to detect of two or more packets have collided by using error check information in the packets. This scheme, termed Pure ALOHA, inefficiently uses available channel capacity. At best, the channel capacity utilization is less than 20 per cent.[4]

This poor channel utilization involved with Pure ALOHA led to the Slotted ALOHA system. In the Slotted ALOHA system, time is divided into segments and each terminal is allowed to start transmitting only at the beginning of the time segment allotted it. In this way, the packet terminals are no longer allowed complete freedom to send packets and the possibility of collisions of data packets is nullified. Channel utilization in the Slotted ALOHA scheme is slightly over 40 per cent.[5]

Following the example of the ALOHA system, other groups researched local area networks. Among the most notable of those was a group at the Palo Alto research lab of the Xerox Corporation. By using the basic idea behind the ALOHA network, that everybody shares the use of

the same transmission medium, they created the system now known as Ethernet. In the Ethernet, the Ether, the universal transmission media, is a single coaxial cable. The channel utilization for Ethernet has been observed in excess of 90 per cent under laboratory conditions.[6]

Ethernet was but one local area network under consideration during the early 1970s. The Hasler company in Switzerland and the University of Cambridge Computing Laboratory in the UK both experimented with techniques very different from Ethernet. In these two efforts the network topology was a loop, where users could transmit only when they were given permission, as opposed to the Ethernet bus topology where everybody has equal rights of access at any time.

One of the most recent developments in local area networks are the use of broadband systems. A broadband network divides the available bandwidth into separate channels, each of which is capable of carrying very high data transmission rates but without having to share with others. The broadband network has been pioneered by the Mitre Corporation in the USA.

3. CHARACTERISTICS

Geography: By definition, local area networks only serve a limited geographic area, such as a room, a building, or a university campus, in general from 100 meters to about 1 kilometer. Wide area networks usually span distances from 1 kilometer to world-wide.

Transmission Rates: One of the many advantages of local area networks is their high transmission rates. Most long distance networks have average speeds of 100-1000 bits per second. In contrast, local area networks have transmission speeds of 1-20 Mega bits per second ($1\text{-}20 \times 10^6$ bps).[7]

Transfer Media: The main transmission media currently in use are coaxial cable and twisted pair telephone cable. The most recent development in transfer media is the use of optical fibre, which has become very popular.

SECTION III

LAN TOPOLOGY

1. BUS

The bus or highway topology is a single communications circuit shared by every node, but the circuit is not joined together (see Figure III.1.1). Information is transmitted to the bus by a node and the signals propagate to all parts of it . All nodes attached to the bus can hear every transmission being made, but usually the signal is directed at a certain node. This type of bus is similar to normal radio broadcast transmissions in which one or a number of transmitters have access to the airwaves through their aerials. Their transmission can be heard by any receiver built to receive them. This type of bus usage is called a baseband bus network.

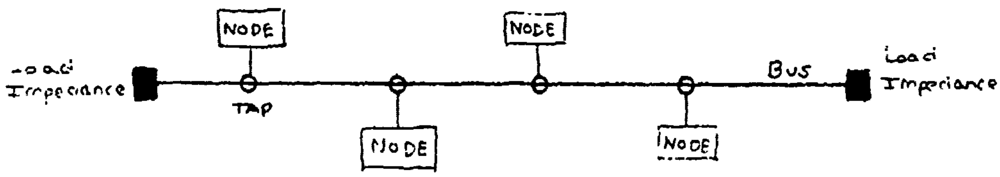

Figure III.1.1

Another type of bus usage is familiar to users of domestic radio and television receivers. Airwaves in these are shared by a number of simultaneous transmissions that use different frequency bands, so that they can be readily distinguished by receivers tuned to the appropriate frequency. Bus networks that use the same principle with a cable substituted for the airwaves are called broadband bus networks.

The two types of bus networks, baseband and broadband, have such significantly different implications that they should be considered separately.

Baseband Bus Network: Baseband means that the signal is unmodulated and so digital information is broadcast as a series of pulses that represent zeros and ones. Therefore, the signal is either on the network or it isn't.[8]

At any given time, only one node may transmit to the bus. If more than one node tries to transmit, the packets will collide and the information will need to be retransmitted. Time division multiplexing is the adopted technique to overcome transmissions. The specific way in which time divisions are allocated depends on the technique. Pure ALOHA used no time division technique, Slotted ALOHA divided time up equally for each node to transmit.

Baseband bus networks have been widely adopted by local area network designers because the bus medium itself is completely passive. There is therefore no need for modems, converters, repeaters, amplifiers, or modulators, allowing the signal to be transmitted at high speeds. In addition to the above, another advantage of the baseband technique is the ease at which additional nodes may be added to the bus. Because all the access and interfacing hardware and software are external to the transmission medium, nodes can be attached practically anywhere on the network without affecting any of the others.

One disadvantage of baseband techniques is that they are unsuitable for usage on circuits that are subject to noise, interference, or random errors. Yet in the restricted environment of a local area

network, baseband signalling is quite suitable. Below is a list of the advantages and disadvantages of baseband bus techniques.

Advantages
- medium is totally passive,
- easy to attach new devices,
- good use can be made of available capacity,
- components are readily available.

Disadvantages
- anyone with the right equipment can listen to the medium without being detected or disrupting normal operations,
- messages can sometimes interfere with each other,
- no automatic acknowledgment of receipt,
- total length of bus is limited to around 1 or 2 kilometers,
- no fairness built into the system since, unless centrally controlled, nodes can use the medium whenever it is free.[9]

Broadband Bus Networks

A broadband bus is similar to the radio airwaves in which different frequencies are allocated to different services. In broadband techniques, a cable (coaxial or optical fiber) carries radio-frequency (RF) transmissions of data suitably modulated onto carrier waves. RF modems are responsible for transmitting and receiving carrier waves and the modulated data.

Since the media used have a very wide bandwidth (300-400 MHz), several frequencies of carrier wave can share the same physical circuits, so the medium can use frequency division multiplexing techniques to share the circuit capacity[10]. By splitting the bandwidth, it can carry both analogue and digital information - data, video, voice, and so on. The same physical network is used by everybody, but in effect it has the appearance of several separate networks.

Broadband systems have been used for some time by providers of cable television circuits. Several television channels are broadcast

along a single piece of cable. Each channel is allocated a particular frequency and the receivers that are plugged into the cable tune in to the frequency appropriate to the channel that they want to see.

The advantages and disadvantages of the broadband bus techniques are shown below.

Advantages
- medium and interface devices are easy to obtain,
- long distances can be covered,
- easy to extend, add new branches, add new devices,
- suited to continuous high-speed traffic,
- can mix video, data, voice, and so on - all on one cable.

Disadvantages
- modems are expensive,
- line amplifiers or repeaters need to be powered reliably.[11]

2. TREE

The tree topology of local area networks is actually a series of bus topologies connected together. Usually, there is a central backbone, or trunk, to which smaller branch buses are connected (see Figure III.2.1)

The tree network is best suited to the broadband method since the transmissions are modulated analogue signals - two frequency channels being used, one for transmitting and another for receiving. Cable splitters and signal amplifiers are easily fitted into broadband bus, with few problems being caused by signal reflections and loss of power owing to the extra devices.

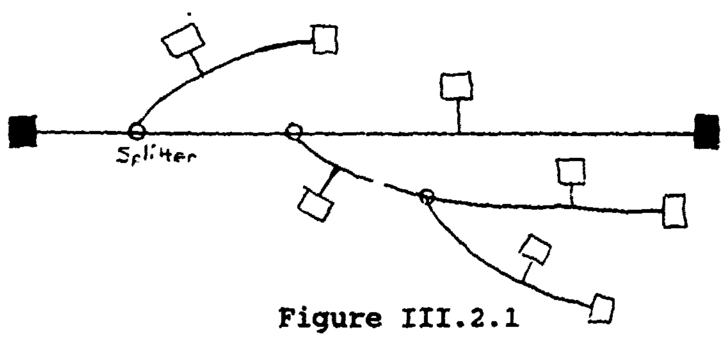

Figure III.2.1

Tree networks using baseband techniques have many more problems. A branch in the cable will mean that the signal will be propagated in two different parts which, unless they are perfectly matched, will travel at different speeds and will be reflected in different ways. Baseband systems that allow tree structures usually run at lower speeds, thereby eliminating one of the distinctive advantages of the single baseband bus system.

One technique adopted for baseband buses is to insert repeaters, but limit the number allowed between any two nodes. This technique, employed by Ethernet, is shown in Figure III.2.2.

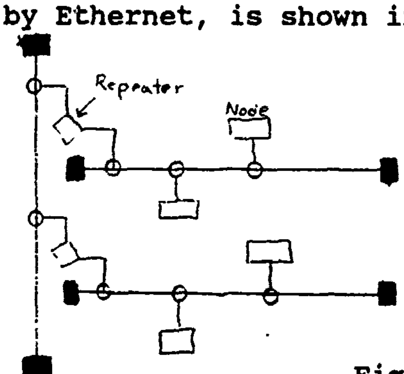

Figure III.2.2

3. STAR

The star shaped network (see Figure III.3.1) is well known both as a typical computer network, in which the center of the star is a computer system that performs processing on information fed to it by the peripheral devices, and as a telephone system, in which the central hub is a switch that interconnects the users on the network [12].

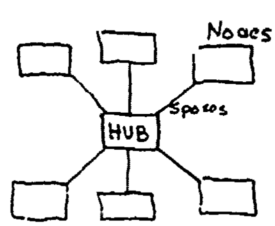

Figure III.3.1

If we define local area networks in that they exist to provide on-site communications between computer-based devices, then the star network is by far the most common topology, since most existing computer systems have on-line access facilities to one or more central computers. Yet, local area networks are further defined as providing interconnection between all the devices on the network. Such networks are typically operated by a device at the hub. The hub device, usually a computer itself, asks, or polls, each peripheral device to determine whether it has data to send. Only when the hub gives its permission can the devices on the spokes send data. If data are intended to go to another terminal, it is the usual practice for the hub controller to process the information and then send the message, rather than effectively just to switch the incoming line to that of the receiver so that messages can pass through without being processed by the hub.[13]

One of the most distinct aspects of a star network is that most of the intelligence needed to control the network can reside in the controlling hub, but can be shared by all devices in the system. This allows relatively "dumb" terminals to operate at an intelligence comparable to the controlling hub. The concentration of intelligence in the hub is a mixed blessing, though, for if the hub ever malfunctioned, the entire system would fail to operate.

Star shaped LANs could also provide a high degree of security protection to prevent unauthorized people from using the network, or unauthorized terminals from accessing certain computer systems. If a link or end device develops a fault it is easy to identify which spoke contains the fault and disconnect if necessary.[14]

A compiled list of the advantages and disadvantages of the star topology can be found on the following page.

Advantages
-ideal for many-to-one configurations,
-suited to "dumb" terminals,
-mixed transmission media and speeds can be used on the spokes,
-each spoke is independent of the rest,
-high security is possible,
-easy fault detection and isolation,
-addressing is easy and centrally controlled,

Disadvantages
-vulnerable to central hub failures,
-complex technology required at the hub is expensive,
-ports are needed at the hub to handle all the lines - either on a one-to-one basis or shared,
-laying cables can be expensive,
-newest technology must be used to obtain all the benefits,
-data rates that can be handled are generally lower than ring or bus topologies, due to hub processing required.[15]

4. RING

A ring network is one in which each node is connected to two, and only two, other nodes (see Figure III.4.1). There is no single node with overall authority over the others with regard to when they can send and receive messages, as is the case in the loop topology. In some local area networks, though, the ring topology is combined with the star to produce a star-shaped ring (Figure III.4.2) or rings connected as a star to a central hub (Figure III.4.3).

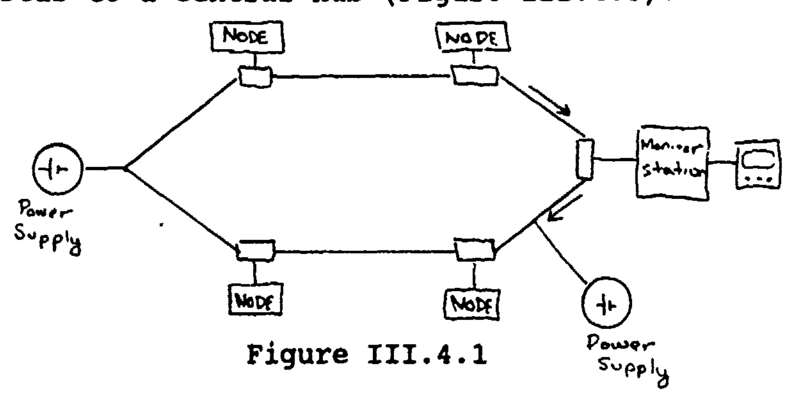

Figure III.4.1

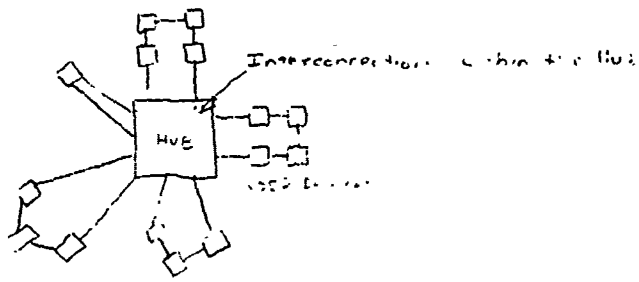

Figure III.4.2

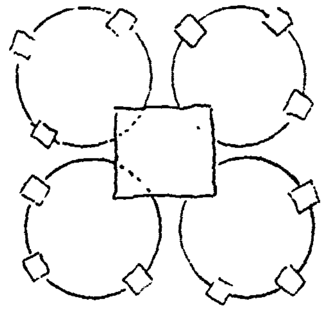

Figure III.4.3

In general, rings do not join the end-devices themselves directly. Instead, the ring consists of a series of repeaters or transceivers joined to each by the physical transmission medium. End-user devices are connected to the repeaters.

The ring topology was devised to eliminate dependence on the central node at the hub of a star, while at the same time providing communications channels between all the devices on the network for high-speed data transmission. Each node on the hub is responsible for some aspect of the network management duties.

Rings almost always transmit in one direction only all the time. Doing so is not a necessity, but it makes the design of the repeaters much easier, and it requires much less sophisticated data transmission protocols to ensure that the information reaches its destination correctly and in sequence with other parts of the same message.

Repeaters are usually made so that they can transmit and receive simultaneously, thus preventing transmission delays.

Because so much relies on the functionality of the links between nodes, complex rings like that shown in Figure III.4.4 have bypass links that eliminate problems arising from failed links or repeaters. Each repeater is bypassed by a link which joins the repeaters on either side of it. If one repeater fails, or any link fails, there is a second or third circuit which can bypass the failed link or repeater.

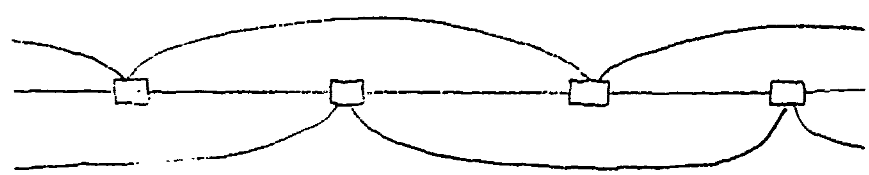

Figure III.4.4

The advantages and disadvantages of the ring topology are listed below.

<u>Advantages</u>
-transmission capacity is shared fairly among all the users,
-no dependence upon a central device,
-error-generating links and nodes can be easily identified,
-checking for transmission errors is easy,
-automatic confirmation of receipt is easy to implement,
-broadcasting to all nodes is easy,
-access is guaranteed, even when the ring is heavily loaded,
-error rate is very low,
-very high transmission rates are possible,
-mixed transmission media can be used.

<u>Disadvantages</u>
-reliability depends on the whole loop and the repeaters,
-difficult to add new nodes without disrupting normal ring operation,
-difficult to lengthen ring,
-repeaters must impose some signal delay,
-a monitoring device is usually needed in practice.[16]

5. LOOP

The loop topology is very similar to the ring topology except for one distinguishing factor - a controlling node (see Figure III.5.1). One node is given overall control in deciding which node can use the circuits and for what purposes. This can be achieved by sending polls out to each node in turn, or by sending out an empty packet that is available for any device to use.

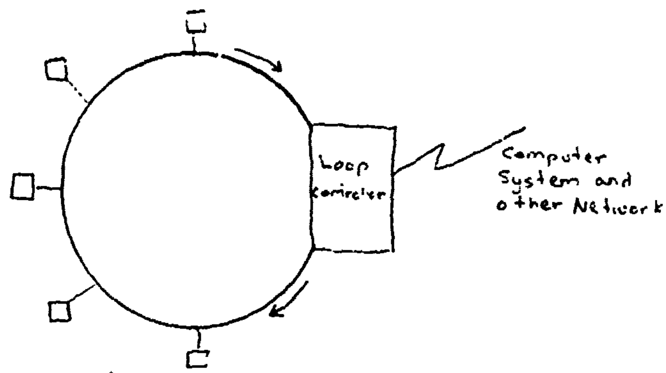

Figure III.5.1

Loops are best suited to handling low-speed devices such as terminals. The controller will be responsible for a number of terminals that will usually be connected to a remote computer system. The controlling device will be a part of another network, probably a star.

The advantages and disadvantages of the loop topology are given below.

<u>Advantages</u>
-very suitable for connecting devices with limited intelligence,
-low cabling costs,
-well-known mainframe terminal handling procedures are used,
-simple to add new devices.

<u>Disadvantages</u>
-system depends on the controller for its operation,
-low data-transmission speeds,
-communications are generally device -- controller, and not directly device -- device.

SECTION IV

CONCLUSION

Local area networks are usually stars, rings, bus, or tree networks since these offer the best compromise between cost, resilience, and efficiency. Fully interconnected and mesh networks require too much cabling and are too complex to install and control for them to be commonly adopted in this context. There are circumstances beyond the scope of this report that call for highly resilient and organized networks to support it. These types of local area networks have specific interconnect requirements and are not general purpose networks. The networks that interconnect JSS radar tracking data and the Comm., Identification, Weapons systems and deployment workstations of the Sector Operations Control Center (SOCC) are examples of highly custom-made networks that serve a specific purpose.

The LANs in the C^2TL (see appendix 1) are mostly general purpose networks. They include Ethernet, Dual Broadband Ethernet, Dual Broadband LAN, Chipcom, Decnet, and JDL T-1. A network of fibreoptic cable connects radar tracking data to processing in the C^2TL. Some of the problems confronting full lab interconnection in the C^2TL have been solved, yet the lab is still not fully interconnected.

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C2TL COMM NETWORK